

THE EMERGENCE OF CERAMIC ROOF TILES
IN ARCHAIC GREEK ARCHITECTURE

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Philip Sapirstein

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Philip Sapirstein, Ph.D.

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This dissertation considers the origins of roof tiles in Greece. After dismissing evidence for predecessors in the Bronze Age, I describe the first archaeologically dated roof from the Old Temple at Corinth, built by the mid-seventh century B.C. Because its exquisitely crafted tiles appear too sophisticated to have been the first invented, I analyze the manufacturing techniques of this so-called “Protocorinthian” tile system.

As the basis for a preliminary hypothesis of the forming and finishing sequence, I present new evidence for reconstructing manufacturing techniques. I conducted extensive fieldwork to examine each of the several hundred examples stored in museums at Corinth, Isthmia, and Delphi. I describe each type of Protocorinthian tile, including new photographs and accurate illustrations rendered from three-dimensional computer models. I infer specific production steps from a typology of surface markings and determine the logical sequence. Each tile must have been formed right-side-up on a clay base mold, its upper surfaces profiled to templates.

In order to test the hypothesis, I created replica tiles at Corinth by working through the full process of mining clay, shaping bricks and tiles, and firing them in an experimental kiln. The experiments confirmed the general validity of the hypothesis and indicated several refinements. I extend these interpretations with ethnographic research. I describe the typical organization of Mediterranean tile makers and reconstruct the scale of pottery production in ancient Corinth when the Old Temple

was built. Combining ethnographic and experimental data, I estimate the labor investment to fabricate its complete roof.

To conclude, I argue that Protocorinthian tiles, though ostensibly complex, are produced with simple techniques that indicate no special expertise designing interlocking roof tiles. However, the fact that these tiles are molded in combination indicates that the designers were imitating an earlier ceramic system with separate covers and pans. An early roof from Olympia has tiles close to the expected prototype for the Old Temple and all other Mediterranean tiled roofs. From the current archaeological evidence, however, it is uncertain whether ceramic tiles were first invented in Etruria, the northern Peloponnese, or central Anatolia.

BIOGRAPHICAL SKETCH

Philip Sapirstein attended the University of Notre Dame at Notre Dame, Indiana, where he developed his interests in studio art, computer graphics, art history, and ancient architecture. He graduated in 1999 with a B.A. in studio art concentrated in printmaking and an art history minor. In 2000, he began graduate study at Cornell University toward a Ph.D. in the Department of the History of Art and Archaeology. Sapirstein has worked for the Greek Architecture Project at Corinth since 1999, where he first encountered the challenge of understanding and illustrating Greek terracotta roof tiles. As a Fulbright scholar for the academic year of 2003-2004, Sapirstein was a regular student member of the American School of Classical Studies at Athens. He returned to the school as the Homer A. and Dorothy B. Thompson Fellow for 2005-2006 to conduct more fieldwork in preparation for his dissertation.

ACKNOWLEDGMENTS

I am grateful for the generous support and guidance that I received while preparing this thesis. I could not have carried out the extensive fieldwork that is its basis without continuous institutional support. I am indebted most of all to the Greek Architecture Project at Corinth of the University of Notre Dame, the field project where I have worked since 1999. There, I was introduced to the roof tiles which are central to this thesis. Supported by a Fulbright IIE Scholarship, I carried out the majority of my museum work with Protocorinthian tiles at Corinth, Isthmia, and Delphi in 2004 after I had completed the regular student program of the American School of Classical Studies at Athens (ASCSA). I returned to Greece for further work at Corinth and Delphi as an associate student member and the 2005-2006 Homer A. and Dorothy B. Thompson Fellow of the ASCSA. I examined Archaic roof tiles in Greece, Turkey, and Italy during that year with the additional support of a Multi-Country Research Fellowship from the Council of American Overseas Research Centers. This grant enabled me to travel to study the roofs at Olympia, Sparta, Ephesos, Acquarossa, and Poggio Civitate that I present in preliminary form in this thesis, not to mention material from many other sites that I will publish elsewhere. The Cornell Graduate School and the History of Art and Archaeology department have supported my education and research since 2000. The university funded much of my fieldwork with three summer stipends and the Hirsch Grant for Archaeological Fieldwork in 2001 and 2002. My department awarded me a Goldring fellowship for my research, for which I have Karen Chirik to thank. The American School at Athens and the American Academy in Rome arranged my research permits for museums in Greece and Italy.

I am grateful to many individuals who have aided this work. The dissertation would not have been possible without the generosity of Robin Rhodes. At the University of Notre Dame, Robin was the first professor who sparked a serious interest in classical archaeology in me. My first experience of fieldwork in Greece was taking part in his Greek Architecture Project at Corinth. Robin taught my fellow crewmembers and me the important skills of how to work with the remains of ancient architecture in the field. I spent many happy months learning to measure and draw the blocks and tiles from the Old Temple at Corinth for his project. When I proposed studying the temple's roof tiles as a dissertation project, Robin offered me unfettered access to the material. He has been particularly generous to allow the presentation in this thesis of my drawings, photographs, and interpretations of the tiles, which anticipate the publication of his own monograph on the full building. With his permission, I have adapted and re-edited texts originally written as a crewmember for the project, which appear in parts of Chapter 3 and the final catalogue of this thesis. I am grateful to Robin for his continued friendship and support throughout the research and writing of this dissertation.

I am indebted to Guy Sanders, director of the Corinth Excavations of the ASCSA, for encouraging my work on the tiles while I resided at Corinth. Guy was the first to push me to test my hypotheses about the manufacturing techniques of Protocorinthian roof tiles by producing full-scale replicas. He instigated our collaborative replications experiments, which are described below in Chapter 6, by providing a workspace, transportation, tools, access to clays, labor, various ice-cold beverages, and well-informed advice. Guy shared with me more than a decade of his experience testing clay deposits and finding ancient kiln sites around the Corinthia.

We were particularly fortunate that John Lambert, a studio artist skilled in large-scale ceramic sculpture and roofing, became interested in the manufacturing of

Protocorinthian tiles. During his coursework at the University of Notre Dame with Robin Rhodes, John invented a novel tile-making system and produced several replicas at the university at the same time as my early research on the ancient fragments at Isthmia and Corinth in 2004. Robin subsequently introduced me to John in Corinth as the ceramicist of the Greek Architecture Project at Corinth. Inspired by his earlier successes making replica tiles, I designed molds and successfully fabricated tiles at Corinth. John demonstrated to Guy and me his efficient methods for mixing large batches of our locally mined clays, and he explained his techniques for striking the upper surface of tile with a board, which are described below in Chapter 6. John went on to create close to thirty full-scale replica Protocorinthian tiles for an exhibition at the Snite Museum of the University of Notre Dame entitled “The Genesis of Monumental Architecture in Greece: the Corinth Project” (opened January 2006), organized by Robin Rhodes.

I am grateful to Guy, John, and Robin for building the experimental kiln whose first load included my replica tiles. Finding the replicas too large to fit into the kilns available in Ancient Corinth, Guy and Robin organized and financed the construction of a wood-fired kiln at Corinth, also with funding from the University of Notre Dame. Over several weeks during the summer of 2006, Lambert built the kiln to his specifications, and Guy oversaw its first firing through several hot August days. The experimental workshop attracted many visitors. I am grateful for the assistance and the company of Betsey Robinson and Ruth Siddall, who gave up many of their free hours to help with my experiments in 2004. My greatest debt is to my wife, herself experienced as a potter. Usually with greater zeal for the project even than myself, Allison Trdan voluntarily toiled at the worksite for much of the 2006 season.

Many others assisted my research on the Protocorinthian tiles in the Corinth museum. Curator Ioulia Tzonou-Herbst, conservator Nikol Anastasatou, Jennifer

Palinkas, and Tasos Kakouros helped by locating, moving, and mending fragments. I benefited from many discussions of the tiles as I worked through the hypotheses described below, especially with Robin, Nikol, and Guy. Above all, however, was John, who spent many hours examining the ancient fragments with me, discussing specific manufacturing techniques and providing his considerable insight as a coroplast. Ruth Siddall of the Department of Earth Sciences at University College London examined calcareous accretions which I had identified on the surfaces of several tiles, showing me which were likely to have been artificially created mortars and how she made the determinations.

I thank many others for assisting my research at other sites. Elizabeth Gebhard, director of the University of Chicago Excavations at Isthmia, permitted my study of the similar Protocorinthian roof tiles from Isthmia. Jean Perras coordinated my visits to the museum, authorized by Zoe Aslamatzidou of the Fourth Ephorate of Prehistoric and Classical Antiquities. I examined other Protocorinthian tiles at Delphi with the permission of Dominique Mulliez, director of the *École française d'Athènes*. Evi Platanitou, general secretary of the *École*, arranged my residence at Delphi. Elena Partida, archaeologist of the Tenth Ephorate, located the fragments for my study, which was authorized by Rozina Kolonia of the Ephorate.

Besides the Protocorinthian tiles, I examined other Archaic roofs which are discussed in Chapter 10. At Sparta, I was granted permission to study material from the Artemis Orthia sanctuary by the British School at Athens and Anna-Basiliki Karapanagiotou of the Fifth Ephorate. I thank Eleni Zavvou, Clare Pickersgill, and Rebecca Sweetman for their assistance locating the sometimes hard-to-find tile fragments in the archaeological museum at Sparta. Reinhard Senff, director of the Olympia Excavations, the German Archaeological Institute, and Xenia Arapogianni of the Seventh Ephorate approved my study of tiles at Olympia. There, Susanne Bocher,

the assistant of the excavations, received me with great hospitality. I am grateful to Maria Pilali of the ASCSA for her invaluable help acquiring formal research permissions from the ephorates prior to all of these visits and for her patience explaining to me the intricacies of the process.

Outside Greece, I discuss an early tile roof from Ephesos, which I first learned about from one of its excavators, Michael Kerschner, of the Austrian Archaeological Institute. Michael invited me to study the material and graciously hosted me during my research in 2005, as did Ulrike Muss in 2007. During my research in Italy, I was indebted in particular to Lexi Eberspracher of the American Academy in Rome, who with great diligence prepared my initial applications to museums, helped arrange visits, and explained many aspects of the Italian permit process that were new to me. Albert and Rebecca Ammerman also gave me valuable advice about preparing the tour. Gregorio Aversa, director of the National Archaeological Museum in Crotona, showed me the surprising local find of an Argive-type antefix tile that he had recently published. I am grateful to Margareta Ohlson Lepscky of the Swedish Institute in Rome for all of her help during my study of the roof tiles from Acquarossa, both those on display in the Viterbo archaeological museum and in the excavation storerooms. Silvia Goggioli permitted me to study early tiles from Poggio Civitate in the Murlo museum.

Many others have encouraged the ethnographic research that has been essential to this thesis. During my year as a regular member of the American School, Guy Sanders repeatedly emphasized the importance of seeking modern analogues to ancient practices. My advisors at Cornell, Andrew Ramage, Peter Kuniholm, and Kathryn Gleason, had well prepared me to be receptive to these methods. Andrew and Peter shared many of their stories and slides of rural Turkish architecture and customs, some of which I was able to see up close during my several seasons at Sardis, thanks

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TABLE OF CONTENTS

Biographical Sketch	p. iii
Acknowledgments	p. iv
Table of Contents	p. x
List of Figures	p. xiii
List of Tables	p. xx
Abbreviations	p. xxi
Preface	p. xxiii
Chapter 1: Introduction	p. 1
Preliminary hypothesis for forming and finishing Protocorinthian tiles	p. 4
Goals for experimental replications and ethnographic research	p. 4
Origins of the Protocorinthian tile system	p. 7
Chapter 2: Methodology	p. 10
Data collected during archaeological fieldwork	p. 10
Experimental replications	p. 11
Chapter 3: Introduction to the Protocorinthian Roofing System	p. 29
Prehistoric antecedents to the Protocorinthian tile system	p. 37
Types of Protocorinthian tiles	p. 56
The total number of tiles on the roof of the Old Temple at Corinth	p. 68
Chapter 4: An Ethnographic Model for Ancient Tile and Brick Production	p. 79
Ethnographic accounts of tile making	p. 79
Brick making and kilns in ethnographic and historical accounts	p. 84
Organization and productivity of tile and brick makers	p. 85
Tile and brick production in antiquity	p. 91
Summary: a model for ancient tile production	p. 96
Chapter 5: Preliminary Hypothesis for the Forming and Finishing of Protocorinthian Tiles	p. 98

Replication experiments at Isthmia	p. 98
Primary forming techniques at Corinth	p. 99
Secondary forming techniques at Corinth	p. 107
Hypothesis for the forming and finishing sequence	p. 113
 Chapter 6: Replication Experiments at Ancient Corinth	 p. 114
Sources of raw materials	p. 114
Paste and slip preparation	p. 124
Primary forming sequence	p. 130
Secondary forming sequence and surface modification	p. 138
Test bricks for quantitative analysis	p. 145
Ancient and experimental firing	p. 146
Results	p. 154
 Chapter 7: Organization and Scale of Corinthian Pottery and Tile Production	 p. 172
Ethnographic models of ancient pottery production	p. 173
Scale and organization of the Classical Athenian pottery industry	p. 179
Pottery and tile production in Ancient Corinth	p. 207
Technology and skills of Protocorinthian tile makers	p. 226
 Chapter 8: The Cost of the Old Temple Roof	 p. 231
Manufacturing Protocorinthian tiles	p. 237
Firing and delivering Protocorinthian tiles	p. 252
Conclusions	p. 263
 Chapter 9: Manufacturing Techniques of the Protocorinthian Tile System	 p. 265
Surface markings of Protocorinthian tiles	p. 265
Refinements to the hypothesis for manufacturing regular tiles	p. 278
Paste Preparation	p. 279
Primary forming sequence	p. 280
The primary forming of the specialized types of tiles	p. 286
Construction of the base mold and template frames	p. 295

Secondary forming sequence and surface modifications	p. 302
Post-firing modifications for setting the tiles	p. 311
Chapter 10: Origins and Significance of the Protocorinthian Roofing System	p. 321
Significance of Protocorinthian tiles to Greek architecture	p. 321
Origins of the Protocorinthian tile system	p. 331
Possible antecedents to the Protocorinthian tile system	p. 334
Conclusions	p. 354
Appendix: Catalogue of Tiles	p. 358
Regular combination tiles	p. 360
Eaves combination tiles	p. 365
Hip combination tiles	p. 368
Ridge combination tiles	p. 371
Free cover tiles	p. 374
Eaves combination tiles used as regular tiles	p. 376
Tiles of uncertain identification	p. 377
Bibliography	p. 384

LIST OF FIGURES

Figure 1.1 A reconstruction of the Old Temple at Corinth	2
Figure 3.1 Plan of Temple Hill in the early sixth century B.C. (Robinson 1976a, p. 214 figure 5)	30
Figure 3.2 The construction system of the Old Temple at Corinth (Rhodes 2003, p. 89 figure 6.10)	32
Figure 3.3 Restored roof of the House of Tiles (Wiencke p. 307, fig. I.104b)	38
Figure 3.4 The conjectural Mycenaean “hybrid” roofing system (Iakovides 1998, p. 132 fig. 57)	38
Figure 3.5 Gla: (<i>left</i>) plan of the South Enclosure and (<i>right</i>) cover tiles stacked in a courtyard to the west of the long passageway in building Z (Iakovides 2001, p. 43 plan 16; pl. 27.55).....	44
Figure 3.6 Wheelmade terracotta gutters on the museum at Gaggera (Selinus)	53
Figure 3.7 The Protocorinthian tile system	58
Figure 3.8 Profiles of Protocorinthian tiles	58
Figure 3.9 The regular combination tile, top (<i>left</i>) and bottom (<i>right</i>).....	59
Figure 3.10 Cover rabbet, Delphi; bottom view from the free edge of the cover (Delphi Museum inv. 21637; AR 1, Le Roy 1967; 3 cm scale card grid at bottom right)	61
Figure 3.11 The eaves combination tile, top (<i>left</i>) and bottom (<i>right</i>)	62
Figure 3.12 The corner of the roof at Isthmia (Hemans 1989, p. 264 fig. 3)	63
Figure 3.13 Geometry of the hip combination tiles.....	64
Figure 3.14 The hip combination tile, top (<i>left</i>) and bottom (<i>right</i>).....	65
Figure 3.15 The ridge combination tile, top (<i>left</i>) and bottom (<i>right</i>).....	66
Figure 3.16 State plan of the Archaic temple of Isthmia. Dashed lines indicate foundations of the Archaic and Classical temples; crosshatched areas represent trenches believed to be robbed-out foundations of the Archaic Temple; the arrow shows the west end of the ridge line (Gebhard and Hemans 1992, p. 26 figure 6)	73
Figure 3.17 Critical values of different roof sizes for producing the excavated tallies	77
Figure 4.1 Buonabitacolo: Treading tile clay in a pit (Hampe and Winter 1965, p. 27 fig. 16)	80
Figure 4.2 Buonabitacolo: Tile shaping tools (Hampe and Winter 1965, p. 27 fig. 17)	80

Figure 4.3 Bivio Segesta: Draping the sheet of clay on the semi-cylindrical cover form (Hampe and Winter 1965, pl. 42.3).....	80
Figure 4.4 Minturno: Tiles laid out in the drying yard (Hampe and Winter 1965, pl. 15.6).....	80
Figure 4.5 Minturno: Flattening a sheet of clay with a board (Hampe and Winter 1965, pl. 15.4).....	82
Figure 4.6 Tile-production equipment at Amochlo, Andros (Birmingham 1967, p. 34)	82
Figure 4.7 Corigliano: Tiles loaded in the kiln (Hampe and Winter 1965, pl. 32.5) ...	91
Figure 4.8 Cover tiles on the roof an abandoned house in Penteskouphia village, west of Corinth.....	91
Figure 4.9 Pallet mold for producing replicas of Roman tegulae (Warry 2006, pl. 2.43)	93
Figure 4.10 Flanged tegula (Rook 1979, p. 299 fig. 16.3)	93
Figure 4.11 Reconstruction of the seventh-century Poggio Civitate, its workshop in the foreground (Tuck 2006, fig. 13.2)	95
Figure 4.12 Stacked pan tiles <i>in situ</i> (Nielsen 1987, p. 94 fig. 9)	95
Figure 4.13 State plan of the workshop, 1984 (Nielsen 1987, fig. 4)	95
Figure 5.1 A parting agent of clay dust and gravel on the undersides of (<i>left</i>) a Protocorinthian tile, Corinth Inv. FT 228 (<i>0.03 m scale card grid at upper right edge of field</i>); and (<i>right</i>) a cover tile from the village of Delphi (<i>approximately equal scale</i>)	100
Figure 5.2 Typical fabric of a Protocorinthian tile (FP 104).....	102
Figure 5.3 Break face across the pan-cover joint revealing the continuous fabric (FP 342).....	102
Figure 5.4 Longitudinal striations exposed beneath flaked slip (FP 326; 6 cm scale card at left; 0.5 mm gradations in inset)	104
Figure 5.5 Sections at the midpoints of several complete tiles; overlays are darkest where several sections coincide.....	104
Figure 5.6 Back face with lateral hollows left by a blade stroke (FP 110; 3 cm scale card grid at bottom right).....	106
Figure 5.7 Protocorinthian regular tile base mold and frame: hypothetical system ...	106
Figure 5.8 Cut marks on the face of the notch (FP 164; 3 cm scale card grid at bottom of field)	108
Figure 5.9 Lengthwise strokes in the cover rabbet (FC 65; 6 cm scale card width at top of field)	108

Figure 5.10 Fingerprints on the lower edge of the free end of the pan (FT 210; 3 cm scale card grid at bottom)	108
Figure 5.11 Back view of a notch with wads of excess slip wiped over the edges (FP 330; 3 cm scale card)	108
Figure 5.12 Fingerprint in the slip of the pan (FC 86; 0.5 mm scale gradations)	110
Figure 5.13 Paint dribbled over the back edge (FP 317; 5 cm grid)	110
Figure 5.14 Chisel marks (scalloped) above scraper casts (temper streaks); original molded surface at the top edge of the field (cover rabbet, FP 163; 0.5 mm gradations)	110
Figure 5.15 Top and bottom of a Protocorinthian tile after primary forming, showing the volumes to be trimmed away in later operations (dashed lines).....	113
Figure 6.1 Resources for tile production in the Corinthia	115
Figure 6.2 Penteskouphia plaques depicting clay mining (<i>above</i>) Berlin, Staatliche Museen 871B (Noble 1988, figure 75); (<i>below left</i>) Berlin, Antikenmuseum F 638 and (<i>below right</i>) F 639 (Xatzedemetriou 2003, plate 3, K11-K12)	117
Figure 6.3 Shoveling clay into baskets (Agios Demetrios site)	121
Figure 6.4 View from the Acrocorinth clay site to SW	121
Figure 6.5 View to the SE (Ag. Antonios chapel to left; clays in scarp to right).....	122
Figure 6.6 The worksite for the replication experiments: (<i>left</i>) overview and	125
Figure 6.7 The <i>kopano</i> used for breaking up mined clay (Psaropoulou 1984, p. 13)	126
Figure 6.8 Clay and mudstone are mixed in the basin before wetting	128
Figure 6.9 After mixing, the paste is too wet and sticky to hold its form	128
Figure 6.10 Wedging a slab of clay by dropping it onto a layer of mudstone	131
Figure 6.11 The first layer of clay packed in the base mold	131
Figure 6.12 The base mold and template frames are ready to pack with clay	134
Figure 6.13 The first slabs are packed into the base mold	134
Figure 6.14 First pass with the strike.....	135
Figure 6.15 Striations on top	135
Figure 6.16 Groove under the slip, FC 29 (<i>6 cm scale card width</i>)	135
Figure 6.17 After striking the replica, the surface is smoothed with a trowel	135
Figure 6.18 Cutting the notch	139
Figure 6.19 Applying slip by hand	139
Figure 6.20 The completed replica tile is left to dry after the bevels are cut	142
Figure 6.21 Surveying the rabbet on the bottom of the replica tile	144

Figure 6.22 Cutting the rabbet with a spatula.....	144
Figure 6.23 The experimental kiln during the construction of the vault	150
Figure 6.24 The completed kiln with the bag wall inside	150
Figure 6.25 Readings from the thermocouple during the experimental firing	152
Figure 6.26 Chiseling the pan rabbet.....	153
Figure 6.27 The fired full-scale replica tile	153
Figure 6.28 Replica: view of break (<i>scale card at top is 6 cm wide</i>)	156
Figure 6.29 Cover-pan joint on the front: (<i>left</i>) replica and (<i>right</i>) FP 110	156
Figure 6.30 Back face and notch: (<i>left</i>) replica and (<i>right</i>) FC 62	156
Figure 6.31 Cover rabbet: (<i>above</i>) replica and (<i>below</i>) FP 325	157
Figure 6.32 Shrinkage rates of test bricks from all clay sites.....	160
Figure 6.33 Linear shrinkage plotted by tempering	163
Figure 7.1 Nikosthenic amphora, 31 cm high (Louvre F 111).....	184
Figure 7.2 Kylix, Penthesilea Painter, 15.5 cm high (Boston MFA 03.815)	184
Figure 7.3 Painters in the Berlin Painter and Achilles Painter workshop (after Oakley 1997, p. 112 chart 9).....	188
Figure 7.4 (<i>above</i>) Belly amphora, Berlin Painter, 52 cm high (Louvre CA 2981); (<i>below</i>) price graffito 10F,21 (Johnston 1979, fig. 12p)	191
Figure 7.5 (<i>above</i>) Pelike, Achilles Painter, 25 cm high (Ashmolean 399: Oakley 1997, pl. 33B); (<i>below</i>) price graffito 2B,9a (Johnston 2006, pl. D)	191
Figure 7.6 Hydria, Manner of the Peleus Painter, 47 cm high (Matheson 1995, p. 202 pl. 156).....	192
Figure 7.7 Faience jar, Nabeul (Maurières and Cambon 2002, p. 80 NA85)	192
Figure 7.8 Djerba: <i>sefrî</i> (Combès and Louis 1967, ph. IV.4).....	197
Figure 7.9 Thrapsano potters: <i>pithari</i> (Xanthoudides 1927, pl. XXI).....	197
Figure 7.10 Hydria, Leagros group (Munich 1717: Xatzedemetriou 2005, pl. 10 K39)	199
Figure 7.11 Shoulder of the Caputi hydria (Milan: Noble 1988, fig. 74).....	200
Figure 7.12 Little master lip cup, turntable (Karlsruhe, Badisches Landesmuseum 67.90: Xatzedemetriou 2005, pl. 9 K37)	202
Figure 7.13 Stick wheel (Saraswati and Behura 1966, p. 20 fig. 1.20).....	202
Figure 7.14 Lekythos, ca. 650 B.C., 9 cm high (Boston MFA 08.281)	208
Figure 7.15 Aryballos of the Utrecht Group (Neeft 1987, p. 229 fig. 133)	208
Figure 7.16 Plan of the Potters' Quarter (ca 280 m N-S: Stillwell 1948, pl. 51)	211

Figure 7.17 Plan of the Tile Works with kilns indicated by arrows (ca. 40 m N-S: Merker 2006, p. 6 fig. 3).....	213
Figure 7.18 Penteskouphia plaque depicting firing (restored from Berlin, Antikenmuseum F 893: Noble 1988, fig. 238).....	214
Figure 7.19 Corinthian Type A amphora (Corinth Inv. C-1977-120: Whitbread 1995, pl. 5.1).....	218
Figure 7.20 <i>Pithari</i> at Phini, Cyprus (Hampe and Winter 1962, pl. 37.1)	218
Figure 7.21 Tinajas near Villarrobledo (Vossen 1972, pl. 6).....	219
Figure 7.22 An open-topped updraft kiln (Rice 1987, fig. 5.22).....	227
Figure 7.23 Thrapsano potters install lintel bricks to support the floor of a kiln built at Asomatos (Hampe and Winter 1962, pl. 3.1).....	227
Figure 8.1 Time for workers alone or in pairs to produce a regular tile.....	238
Figure 8.2 <i>Pithari</i> -production in parallel by Thrapsano potters at Asomatos (Hampe and Winter 1962, pl. 13.2).....	239
Figure 8.3 (<i>left</i>) Circular “dance” on the clay, (<i>right</i>) into a conical mound, Nabeul (Lisse and Louis 1956, p. 33 fig. 9 and p. 32 fig. 11, respectively)	242
Figure 8.4 Attic black-figure skyphos (Cambridge, MA, Sackler Museum 1960.321: Xatzedemetriou 2005, pl. 12 K41)	243
Figure 8.5 Optimal kiln stacking arrangement for 104 Protocorinthian tiles inside a 2.15 m square (view in plan)	254
Figure 8.6 Daily work schedule for producing 23-25 tiles.....	261
Figure 9.1 Laminated fabric (FR 117; 3 cm scale grid below)	268
Figure 9.2 Dragged temper tracks (FT 211).....	268
Figure 9.3 Free side of the pan (FP 344; 3 cm scale grid below).....	270
Figure 9.4 Free sides of eaves pans formed against a vertical frame: (<i>left</i>) FP 161 (3 cm grid scale at top); (<i>right</i>) FT 235 (face height ca. 6 cm)	271
Figure 9.5 Eaves pan rabbet, free edge (FT 211; front face at bottom; 3 cm grid scale)	274
Figure 9.6 Back free corner of the pan with incised guidelines, weathering; (FP 109; 6 cm scale).....	274
Figure 9.7 Bottom view, FP 327, whose cover rabbet was omitted (5 cm grid).....	279
Figure 9.8 Back face of the pan with extruded upper edge (FP 76).....	280
Figure 9.9 Thinned parting agent under the cover-pan joint (FP 157; 6 cm scale)....	281
Figure 9.10 Transverse bowing (front face to left; sections near midpoint)	283
Figure 9.11 Comparison of transverse sections; (<i>below</i>) longitudinal sections	283

Figure 9.12 System for shaping Roman tegulae: (<i>left</i>) stages of production; (<i>right</i>) distortions from an ill-tensioned wire (Rook 1979, pp. 300-301 figs. 16.3-4)	285
Figure 9.13 Profiles of the eaves tile	287
Figure 9.14 System for shaping eaves tiles	287
Figure 9.15 Features of the hip tile	289
Figure 9.16 System for molding hip tiles	289
Figure 9.17 Geometry of the hip cover; top/bottom (<i>left/right</i>) (FC 79; 3 cm grid)	289
Figure 9.18 Ridge pan, FT 227, view from the free end; the peak line bends to the left at the attached side of the pan (i.e., at the top of the field; 3 cm scale grid)	291
Figure 9.19 Transverse sections of covers and pans of ridge tiles	292
Figure 9.20 Profile of the ridge cover: (<i>left</i>) domed cover, FC 61, view from back; (<i>right</i>) peaked cover, FR 108, top (3 cm grid on both scales)	293
Figure 9.21 Ridge tile molding: (<i>left</i>) base mold and templates; (<i>right</i>) a tile after the primary forming with its pan bevels already cut	293
Figure 9.22 Free cover tile with nail; top/bottom (<i>left/right</i>) (FC 98; 6 cm scale)	294
Figure 9.23 Experimental hip tile base mold	297
Figure 9.24 Raised lip (<i>left</i>) along the free edge of the rabbet, FP 329 (front edge at bottom of field; 5 cm grid)	304
Figure 9.25 Top view of the notch, FP 342 (back at bottom of field)	307
Figure 9.26 Cracked slip (FC 114; 3 cm scale grid at left)	307
Figure 9.27 Slip wiped over the rough surface of the attached face of the cover; cracking at the attachment with the pan (FC 62; 6 cm scale at bottom of field)	308
Figure 9.28 Damage from spalling on the pan (FT 228; 3 cm scale grid at left)	309
Figure 9.29 Front view of the wedge added to the eaves pans at Isthmia; untempered clay is exposed in the break at the tip—compare to the tempered clay exposed in the break at the left (IT 219; Broneer 1971, AT 20, p. 52, fig. 60; 5 cm grid)	310
Figure 9.30 Setting order of the Protocorinthian tiles on the roof (eaves hip tile at the bottom right corner)	312
Figure 9.31 Round countersink and nail shaft with iron corrosion; free cover FC 109 (ruler at top of field)	316
Figure 9.32 Ridge tile with nail holes and countersinks drilled after firing (FR 117; 3 cm scale grid at bottom left)	316

Figure 9.33 Right-handed eaves tile re-cut into a regular tile (Isthmia IT 372; Broneer 1971, AT 13): (<i>left</i>) front face (3 cm scale card grid); (<i>right</i>) bottom view (front edge at top of field, pan rabbet at left; 5 cm background grid)	319
Figure 10.1 Wikander's hypothetical "stemma" of seventh-century roof systems (Ö. Wikander 1992, p. 160 fig. 5).....	335
Figure 10.2 Olympia "Roof 1": (<i>above</i>) corner showing overlaps; (<i>below</i>) regular tile profile (the eaves hip tile is restored by analogy to the regular hip tiles)	340
Figure 10.3 Roof of the Orientalizing Workshop at Poggio Civitate (Nielsen 1998, p. 97 fig. 2)	349

LIST OF TABLES

Table 3.1 Findspots and quantities of tiles excavated at Gla	48
Table 4.1 Wages and costs for seventeenth-century English brick makers, 8,000 bricks	87
Table 5.1 A hypothetical forming sequence for regular Protocorinthian tiles at Corinth inferred from surface markings	112
Table 6.1 Recipes for 100 liters of clay with 0%, 20%, and 30% tempering.....	159
Table 6.2 Linear shrinkage and weight loss for test bricks	162
Table 6.3 Linear shrinkage for untempered and heavily tempered bricks	164
Table 6.4 Fired and optimal-plasticity paste volume in a regular tile	166
Table 6.5 Individual time cost (minutes) for paste preparation per tile	169
Table 6.6 Individual time cost (minutes) for forming one tile	170
Table 7.1 Modes of pottery production in the Roman economy (Peacock 1982)	174
Table 7.2 Numbers of prize amphoras from 566 to ca 300 B.C. (after Bentz 1998) .	182
Table 8.1 Materials required to produce 100 liters of fired tile fabric	235
Table 8.2 Paste preparation rates by foot treading	245
Table 8.3 Hours to retrieve clay and mudstone for 25 tiles.....	250
Table 8.4 Minimum time to produce 1,491 tiles and 30 molds without failures	262
Table 9.1 Surface markings grouped by manufacturing stages.....	267

LIST OF ABBREVIATIONS

<i>AA</i>	<i>Archäologischer Anzeiger</i>
<i>AD</i>	<i>Αρχαιολογικόν Δελτίον</i>
<i>AJA</i>	<i>American Journal of Archaeology</i>
<i>AM</i>	<i>Mitteilungen des Deutschen Archäologischen Instituts, Athenische Abteilung</i>
<i>ARCHON</i>	Crielaard, J. P., V. Stissi and G. J. van Wijngaarden, eds. 1999. <i>The Complex Past of Pottery. Production, Circulation and Consumption of Mycenaean and Greek Pottery (Sixteenth to Early Fifth Centuries B.C.). Proceedings of the ARCHON International Conference, held in Amsterdam, 8-9 November 1996</i> , Amsterdam.
<i>ASAtene</i>	<i>Annuario della Scuola archeologica di Atene e delle Missioni italiane in Oriente</i>
<i>Atti Taranto</i>	<i>Atti del Convegno di Studi sulla Magna Grecia</i>
<i>BCH</i>	<i>Bulletin de correspondance hellénique</i>
<i>BSA</i>	<i>Annual of the British School at Athens</i>
<i>Corinth XX</i>	Williams, C. K. II and N. Bookidis, eds. 2003. <i>Corinth, the Centenary: 1896-1996 (Corinth XX)</i> , Princeton.
<i>Ergon</i>	<i>Το Έργον της Αρχαιολογικής Εταιρείας</i>
<i>From Huts to Houses</i>	Brandt, J. R. and L. Karlsson, eds. 1997. <i>From Huts to Houses: Transformations of Ancient Societies. Proceedings of an International Seminar Organized by the Norwegian and Swedish Institutes in Rome, 21-24 September 1997</i> , Stockholm.
<i>ICCA XV</i>	Docter, R. F. and E. M. Moormann, eds. 1999. <i>Proceedings of the XVth International Congress of Classical Archaeology, Amsterdam, July 12-17, 1998. Classical Archaeology Towards the Third Millennium: Reflections and Perspectives</i> , Amsterdam.
<i>JdI</i>	<i>Jahrbuch des Deutschen Archäologischen Instituts</i>
<i>JFA</i>	<i>Journal of Field Archaeology</i>

- JHS* *Journal of Hellenic Studies*
- JRS* *Journal of Roman Studies*
- Les ateliers de potiers* Blondé, F. and J. Y. Perreault, eds. 1992. *Les ateliers de potiers dans le monde grec aux époques Géométrique, Archaique et Classique: Actes de la Table Ronde organisée à l'École française d'Athènes (2 et 3 octobre 1987) (BCH Supplement 23)*, Paris.
- Midas* Kealhofer, L., ed. 2005. *The Archaeology of Midas and the Phrygians: Recent Work at Gordion*, Philadelphia.
- Munsell Charts* *Munsell Soil Color Charts, New Windsor*, 2000.
- OJA* *Oxford Journal of Archaeology*
- ÖJh* *Jahreshefte des Österreichischen archäologischen Instituts in Wien*
- OpAth* *Opuscula Atheniensia*
- PBSR* *Papers of the British School at Rome*
- Pottery Manufacturing Processes* Livingstone Smith, A., D. Bosquet and R. Martineau, eds. 2005. *Pottery Manufacturing Processes: Reconstitution and Interpretation. Acts of the XIVth UISPP Congress, University of Liège, Belgium, 2-8 September 2001 (BAR International Series 1349)*, Oxford.
- Praktika* *Πρακτικά της εν Αθήναις Αρχαιολογικής Εταιρείας*
- Roman Brick and Tile* McWhirr, A., ed. 1979. *Roman Brick and Tile: Studies in Manufacture, Distribution and Use in the Western Empire (BAR International Series 68)*, Oxford.
- The Many Dimensions of Pottery* van der Leeuw, S. E. and A. C. Pritchard, eds. 1984. *The Many Dimensions of Pottery: Ceramics in Archaeology and Anthropology*, Amsterdam.
- Tiryns* *Tiryns: Forschungen und Berichte*

PREFACE

In many ways this is an unusual study. I focus on the single question of how and in what context terracotta roof tiles were introduced into Mediterranean architecture. Besides reviewing the contextual and stylistic evidence usually presented by architectural historians, I analyze the manufacturing techniques of the first ceramic tile systems. Such an approach is essential to understand this technological problem. My investigation relies on three principal methods, which have been underutilized in classical archaeology: the analysis of surface markings on ancient objects, hypothesis-testing by experimental archaeology, and inference by ethnographic analogy. Along the way, I explore the broader consequences of these three lines of inquiry to the study of ancient architecture and technology.

First is the detailed analysis of surface markings, by which I infer the forming and finishing sequence of the original object. The detailed documentation of the evidence that this approach demands has driven my extensive use of computer technology. For the important features described in the text, I present forty close-up photographs selected from the more than ten thousand digital photographs collected during the research. In order to make the fairly confusing remains of smashed terracotta tiles more intelligible to the reader, I illustrate the tiling systems with three-dimensional models rendered on a computer. By combining standardized profiles and averaged measurements taken of several hundred ancient fragments, I have designed the models for these figures as accurately as possible. The collection of three-dimensional measurements and profile drawings for the computer models has influenced my description and analysis in the text. For example, while creating and manipulating the models, I learned that every type of tile on an early Protocorinthian or Argive tile roof is geometrically similar. My descriptions of the Protocorinthian tile

system in Chapter 3 follow from the discovery. As argued in Chapter 10, this fact also suggests that the unified, modular design of early tile roofs prepared Greek architects for designing early stone Doric temples.

The investigation of ceramic ethnography is the second line of inquiry. By summarizing the reports by ethnographers who studied modern brick and tile makers, I develop a model for tile production in Chapter 4. This model informs the hypothesis for the manufacturing of early Protocorinthian tiles proposed in Chapter 5. Using analogies to modern practices, I am able to associate surface markings on the ancient tiles with specific production steps. However, the Protocorinthian tile system comes from the earliest securely dated archaeological context with roof tiles. Because its designers cannot have been part of a well-established tradition of tile making, they must instead have been potters. Thus, in Chapter 7, I reconstruct the organization and skill in the contemporary Corinthian pottery industry by comparing the considerable evidence for Archaic pottery workshops in Corinth to modern analogues. The ancient Athenian pottery industry is an intermediary. From a quantitative analysis of vases by prolific fifth-century painters, I estimate no more than 100 to 150 artisans in the Attic red-figure industry at its peak. At the time of the first Protocorinthian tiles, Corinth was considerably smaller than Athens. Of about a dozen skilled Corinthian potters active at the time, just one may have led a small team who made the first tiled roof.

A third line of inquiry in the dissertation is experimental. In order to test my hypotheses about how early tiles were manufactured, I conducted the replication experiments described in Chapter 6. Besides some modifications to the initial hypothesis, the project also collected useful data on the performance characteristics of Corinthian clays. Furthermore, I recorded how long it took to execute each production step during the experiments. This timing data enabled the economic study of the production of a whole roof. First, in Chapter 2, I defend the validity of the approach by

means of the least-effort principle, a behavioral model useful for reconstructing the costs of ancient labor. After describing the replication experiments (Chapter 6) and the early Corinthian pottery industry (Chapter 7), I return to the cost estimate in Chapter 8. With the timings of production stages recorded both in the experiments and by ethnographers, I develop a detailed picture of the organization and duties of a hypothetical team producing Protocorinthian tiles. In the end, I estimate that as few as four workers could have fabricated and delivered the tiles for an entire roof in just one production season of about a hundred days.

In Chapter 9, I return to the technology of ancient tiles and refine the initial manufacturing hypothesis proposed in Chapter 5. I develop a typology of surface markings that can be used to infer the production techniques in any tile-making tradition, and I describe in detail the manufacturing and installation of ancient Protocorinthian tiles. In the final chapter, I compare the technological and archaeological evidence for the origins of terracotta tiles. It is traditionally assumed that the Corinthians invented tiles and subsequently diffused the technology to peripheral centers. However, the technical evidence presented in this thesis indicates that the first Greek tile roofs almost certainly developed in a Peloponnesian center outside the Corinthia. Furthermore, the Etruscans are as likely as the Peloponnesians to have invented interlocking ceramic roof tiles, although the archaeological evidence does not indicate the priority of one region over the other. These conclusions are supported by the three lines of inquiry described above, and each chapter builds upon the previous in a logical sequence. Therefore, in order for the results of this dissertation to be most intelligible, it must be read from start to finish.

CHAPTER 1: INTRODUCTION

This thesis analyzes the origins and technology of ceramic roof tiles in the Mediterranean. The first examples known from the Iron Age belonged to the Old Temple at Corinth (Figure 1.1).¹ At present, the evidence suggests that the Corinthians developed a complex new roofing technique for this building by the middle of the seventh century B.C.² It has been debated whether this so-called Protocorinthian tiling system³ was the first invented. With the earliest well-preserved ceramic roof, however, the Old Temple is essential to understanding the origins of all roof tiles, which soon became a standard component of Greek temples. Therefore, the technical analysis of the Protocorinthian tile system undertaken by this thesis provides critical insights into the development of Greek monumental architecture.

Tiles represent a significant improvement over the thatch used to roof huts in the Geometric period. Ceramic tiles are much sturdier, require less maintenance, and fireproof a vulnerable component of the building.⁴ However, the tiles are also considerably heavier than thatch, demanding stronger walls for support. As a result, roof tiles and coursed stone masonry are complementary techniques that both appear for the first time in Archaic architecture at the Old Temple of Corinth. The whole structure of the temple has been conditioned by the massive tile roof.⁵ Furthermore, its

¹ Rhodes 1984, 2003; Robinson 1976a, 1976b, 1984, 1986; Roebuck 1955; Weinberg 1939. Bookidis and Stroud 2004 have recently reasserted the traditional identification of the temple's deity as Apollo, although in this thesis its predecessor is called the 'Old Temple' to distinguish it more clearly from the sixth-century temple. In the exhibition entitled "The Genesis of Monumental Architecture in Greece: the Corinth Project" at the Snite Museum of the University of Notre Dame and the accompanying symposium *Issues in Architectural Reconstruction* (held Jan. 22nd 2006), Rhodes prefers an identification as the temple of Zeus and Hera.

² Ö. Wikander 1992, pp. 152-153; Winter 1993, pp. 12-18. Reported dates for Protocorinthian roofs: Broneer 1971, pp. 1, 3-12, 55; Gebhard and Hemans 1992, pp. 34-40; Rhodes 1984, pp. 43-60, 104-108; Robinson 1976a, p. 212; Robinson 1984, pp. 55-57.

³ Winter 1993, p. 12 adopted the term "Protocorinthian" from Le Roy 1967.

⁴ Ö. Wikander 1988, pp.206-207; 1990, p. 289.

⁵ Rhodes 2003, p. 88.

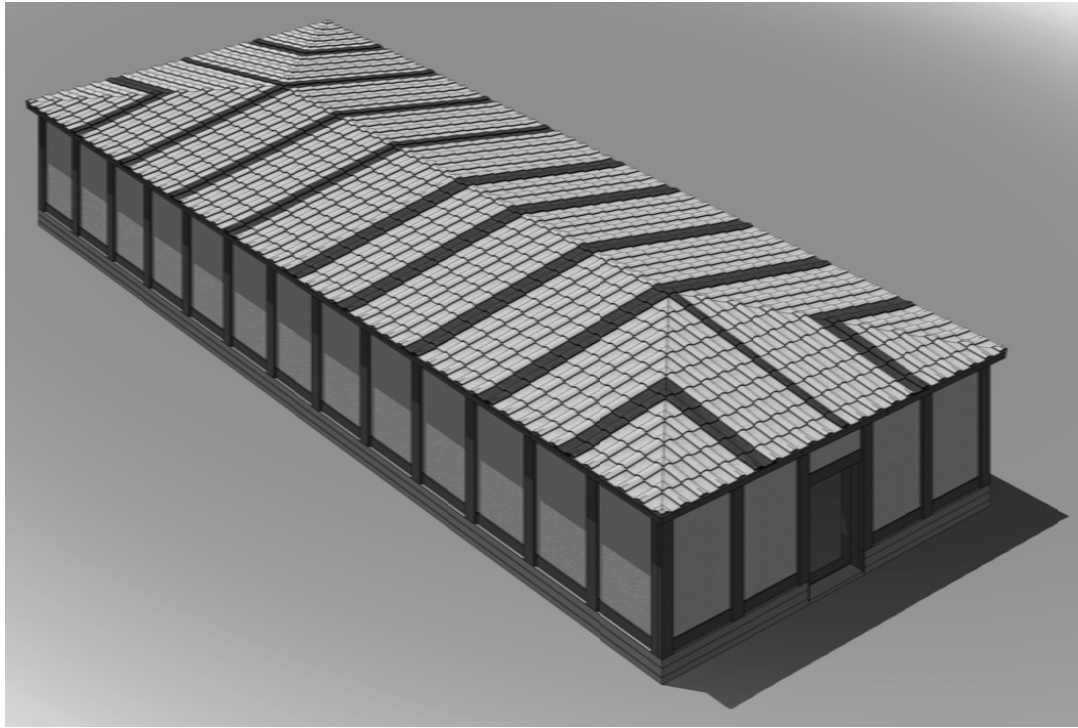


Figure 1.1 A reconstruction of the Old Temple at Corinth

installation required that the many hundreds of identical elements overlapped to form a watertight seal. The design of the interlocking system and the development of new methods to mass produce standardized units were significant challenges to ancient craftsmen. Because the tiles are shaped from clay, Corinthian potters must have been largely responsible for these innovations.

Until recently, architectural terracottas were overlooked as evidence for restoring the appearance of temples during the important early period in the development of Greek monumental architecture.⁶ Tiles are often the only identifiable remains of major seventh-century buildings. Other elements from the superstructure are seldom preserved, and foundations were often removed by later construction or stone looting. Consequently, this thesis advances new methods for reconstructing early architecture by analyzing roofs.

⁶ e.g., Coulson 1990, p. 11.

I have investigated the manufacturing techniques of Protocorinthian tiles in order to understand this technological advance. Although the Old Temple roof is the primary subject, I examined other Protocorinthian tiles from Corinth, Isthmia, Perachora, and Delphi⁷ to construct a hypothesis for the forming and finishing sequence of each type of tile at Corinth.

First in the thesis, I explain the methodology (Chapter 2). After introducing the history of excavations of Protocorinthian tiles, I critically review the evidence for Bronze Age predecessors to the system and describe the types of the tiles in detail (Chapter 3). I develop a preliminary hypothesis for the manufacturing techniques of Protocorinthian tiles by reviewing ethnographic studies of tile makers and by analyzing surface markings (Chapters 4, 5). Next, I describe replication experiments carried out in Ancient Corinth to test the hypothesis (Chapter 6). In light of the experimental results and ethnographic parallels, I refine the preliminary hypothesis. By comparing the archaeological evidence for pottery production in seventh-century Corinth to analogues in the ethnographic record, I create a model of the size and skills of the tile-making team who fabricated the roof for the Old Temple (Chapter 7). I estimate the cost of this job using the ethnographic and experimental data (Chapter 8). I then synthesize the evidence for the manufacturing techniques of all types of Protocorinthian tiles into a complete model from production to installation (Chapter 9). I conclude that, despite its apparent complexity, the entire roofing system was derived by logical modifications to a single template. Finally, I offer new explanations for the origins of Protocorinthian tiles and their relationship to other seventh-century roofing systems (Chapter 10).

⁷ See below, note 189 and Chapter 3 in general. Besides the tiles from Corinth, I also examined 137 fragments of the Protocorinthian roof stored in the Isthmia museum and 18 fragments of Protocorinthian tiles at Delphi. I thank Elizabeth Gebhard and Dominique Mulliez for their permissions to study the Protocorinthian tiles at Isthmia and Delphi, respectively.

1.A) Preliminary hypothesis for forming and finishing Protocorinthian tiles

Because relevant historical information for early seventh-century Corinth is lacking, the Protocorinthian tiles are analyzed with processual methods developed primarily in prehistoric archaeology.⁸ An initial hypothesis is created by a process of reverse engineering. By associating surface markings on ancient tiles with specific tools and gestures, the probable sequence of operations to fabricate a full tile is extrapolated. This process is not entirely theoretical. A basic familiarity with traditional methods of producing Mediterranean tiles and with the working properties of clay is necessary in order to make reliable inferences from surface markings. The result is a “forming and finishing sequence” comprised of discrete “production steps” (e.g., see below, Table 5.1).⁹

This sequence, which is the preliminary hypothesis, is incomplete since it represents only production steps that left markings on the surfaces of Protocorinthian tiles. However, some processes essential to any ceramic technology, such as the firing, may be surmised. Analogues from modern traditional tile producers indirectly suggest several other production steps.

1.B) Goals for experimental replications and ethnographic research

Speculative gaps in the preliminary hypothesis may be bridged with information from the creation of replicas and a review of ethnographic parallels. The

⁸ Arnold 1985; Ascher 1961b; Binford 2001, especially pp. 114-159, 316-359; [1983] 2002, pp. 23-26; David and Kramer 2001; Kramer 1985; Snodgrass 2006, pp. 63-77; van der Leeuw and Torrence 1989, p. 9; Wylie 1985.

⁹ Terminology adapted from Rye 1981, pp. 1-5, 58-96. The method is usually applied to prehistoric artifacts, e.g.: Ascher 1961b; Gelbert 2005; Gillis 1988; Henrickson 1986, 1993; Hodges 1965; Livingstone Smith 2001; Roux and Courty 2005; Powell 1995; Semenov 1964; Vandiver 1987; van der Leeuw 1976; Vitelli 1993. Studies of pottery production techniques into historical periods include Franken 2005; Franken and Kalsbeek 1975; Livingstone Smith et al. 2005; Noble 1988; Schreiber 1999; Vandiver and Koehler 1986; Whitbread 1996. The forming and finishing sequence is similar to the *chaîne opératoire*, a behavioral concept articulated in the theory of technology: David and Kramer 2001, p. 140; Keller 2001; Lemonnier 1992; Roux and Matarasso 1999, pp. 47-56; van der Leeuw 1993; Vidale, Kenoyer, and Bhan 1992.

Protocorinthian roofing system has many complex interlocking types, but each form is closely related to the regular tile. Thus, the focus of the replication study is the regular combination tile, not only because this type was the most common on the roof,¹⁰ but also because the other forms can be derived geometrically from the regular tile with relatively little difficulty.¹¹ The investigation leads to two principal results. First, the hypothesis for the manufacturing sequence of regular tiles is refined. Second, the labor investment for the full roof is extrapolated from the refined hypothesis.

Since many aspects of the hypothesis cannot be tested directly, it is preferable to think of this study as an extended exercise of developing analogies for how Protocorinthian tiles might have been produced.¹² The hypothetical production sequence may be refined, but without more complete experimental controls for every step of the process it cannot be fully supported or rejected. Ethnographic models indicate further restraints on the hypothesis which reduce it to a parsimonious and logical sequence of production steps, despite some interchangeability of options within certain stages. The modified hypothesis is neither final nor absolute, but rather it takes the form of a partially ordered set of necessary production steps along with possible alternatives. Further refinement is impossible because of equifinality, when several equally plausible alternatives might have led to the same patterning of the archaeological data. By presenting multiple alternative hypotheses, the degree of confidence at which each production step has been reconstructed is made explicit.¹³ For elaborately crafted ceramic objects like Protocorinthian tiles, however, the forming and finishing sequence is supported by strong analogies to the experimental

¹⁰ See below, p. 68f. In any plausible configuration of a Protocorinthian roof, the regular tiles are 75% to 85% of the total count of tiles from the roof.

¹¹ See below, Chapter 9.

¹² Ascher 1961a, pp. 807-812; 1961b, pp. 322-324; Binford 2001; David and Kramer 2001, pp. 43-54; Gould and Watson 1982; Ingersoll, Yellen, and MacDonald 1977; Saraydar and Shimada 1973; Stahl 1993; Wylie 1985; Yalman 2005.

¹³ Chamberlin 1944; Trigger 1998, p. 31.

and ethnographic data.¹⁴ Although often underutilized for archaeological interpretation in general,¹⁵ the results of replication tests and ethnographic research in this case may be combined into a richly textured description of the ancient production environment and the processes for creating Protocorinthian tiles.

The second component of the replication study is a detailed estimate of the labor and materials needed to fabricate the whole roof of the Old Temple. This economic analysis takes advantage of the complementary nature of the experimental and ethnographic data. With adequate controls, the replication experiments approximate the times required for each production step in antiquity. The production organization and work rates in pre-modern pottery and tile industries are also recorded in the ethnographic literature. The refined forming and finishing sequence is a list of alternatives in the production sequence, but further simplification is required before calculating the minimum time requirements for creating the tiles. Ultimately the analysis determines a limited range of man-hours required to fabricate an entire Protocorinthian roof (primarily from experimental data) and the probable number of laborers who participated in the project (primarily from ethnographic parallels).

This latter economic component of the study follows upon experiments conducted by William Rostoker and Elizabeth R. Gebhard, who replicated similar roof tiles from the Archaic Temple to Poseidon at Isthmia.¹⁶ Exceeding the Isthmia experiments in scope and detail, the research presented in this thesis more closely resembles the methodologies employed in three recent architectural studies in the Classical world: Janet DeLaine's economic analysis of the Baths of Caracalla, the estimate of the fabrication of a small tiled roof in Hellenistic Gordion by Robert C.

¹⁴ Ascher 1961a, pp. 809-812; Binford 2001, pp. 44-52; Mathieu 2002, p. 8.

¹⁵ Longacre 1992 advocates this approach, starting with ethnographic evidence and archaeological data first to develop questions that drive subsequent experiments.

¹⁶ Rostoker and Gebhard 1981, especially pp. 224-226.

Henrickson and M. James Blackman, and Peter Warry's study of the manufacturing techniques for Roman tiles in Britain.¹⁷

1.C) Origins of the Protocorinthian tile system

Excavations to date indicate that Corinth was first to invent ceramic roof tiles. The comprehensive review of the archaeological evidence for early tile systems undertaken below suggests that no tile-making tradition existed before the Corinthians developed the Protocorinthian tile system.

However, the origins of the system are controversial because of the apparent sophistication of the tiles. The tiles are well crafted, greatly exceeding the quality of the plain covers and stamped antefixes in modern Greek vernacular architecture. Each regular Protocorinthian tile would have weighed about 31 kg on average and measured 64-70 cm in length and width. Individual tiles are molded in combination, that is, with both a cover and pan attached in a single unit (see below, Figure 3.9). Notches, bevels, and rabbets were necessary for the combination tiles to interlock. Although it is possible that tiles of large dimensions and high quality could have been a novel invention of Archaic Corinthian potters, it is difficult to explain why the designers chose to make each tile in combination without knowledge of some preceding tile roof. The articulation of both cover and pan in each Protocorinthian roof tile indicates a modification to an existing tile roof system with separate cover and pan tiles.

As a result, the tiles appear so complex that some scholars propose a multi-stage evolutionary sequence leading up to the Old Temple roof despite the lack of any evidence for such a development in the archaeological record.¹⁸ Others have argued instead that ceramic roof tiles were an unprecedented Corinthian invention, but the

¹⁷ DeLaine 1997; Henrickson and Blackman 1999; Warry 2006.

¹⁸ Schwandner 1990 articulates this position well.

shapes of the tiles imitated an earlier roofing technique with covers and pans made of perishable materials that left no traces in the archaeological record.¹⁹

The hypothesis for the forming and finishing technique of the Protocorinthian roof tiles developed in this thesis sheds new light on this debate. The tiles, despite their apparent complexity, are generated using simple techniques that were logically derived from well-known ceramic technologies of the era. Specialist potters could have invented the Protocorinthian tile system specifically for the project of the Old Temple. However, the tiles cannot have been entirely unprecedented. It will be argued in the final chapter that the choice to articulate separate covers and pans must have followed some previous ceramic roofing system whose covers and pans were articulated for a practical function.

Therefore, a multi-stage evolution based on an assumption of complexity is unnecessary. Instead, the Corinthians need only have had a limited understanding of the predecessor, which may have been a roofing system developed in another center. A review of the regional tile systems from the seventh century B.C. reveals several candidates. A Peloponnesian type of roof represented best by fragments from Olympia may have been the precursor to the roof of the Old Temple. Otherwise, the tile systems developed in Etruria are potential sources for inspiration. The arguments for a predecessor roof to the Protocorinthian system offered here have strong stylistic and technical support. These analyses suggest that further excavation and research in the northern Peloponnese may eventually uncover evidence of a prototype for the traditional Mediterranean tiled roof certainly dating earlier than the Old Temple. Because the eighth- and seventh-century history of central Italy has been altered dramatically by recent finds, the prototype tile system may have developed in Etruria instead. In conclusion, the contextual evidence that indicates Corinth first developed

¹⁹ Ö. Wikander 1992 promotes this viewpoint.

tiles may be an accident of preservation. However, if tiles were invented elsewhere, this breakthrough probably did not occur long before the construction of the Old Temple.

CHAPTER 2: METHODOLOGY

Roof tiles preserve a rich record of how they were shaped. Tiles are built in pliable clay, and tools used at different stages of the manufacturing process leave distinctive impressions on the surface of the clay. These marks are made permanent by firing and, along with later chiseling and weathering stains, become an indelible record of the production and use of the tiles. The analysis and interpretation of these marks permit the inference of the ancient forming and finishing sequence.

2.A) Data collected during archaeological fieldwork

During fieldwork, the tool casts and other surface markings, a complete set of measurements accurate to the millimeter, the weight, and a fabric description were recorded for every tile fragment.²⁰ Diagnostic features were photographed, and well-preserved pieces were drawn in full-scale sections. The note sheets and section drawings were scanned for entering into a database, allowing the complete documentation for any object to be retrieved rapidly. The critical measurements of all the tiles in the study set were included in the database for statistical analyses of the dimensions of the roof. Tiles are mass-produced objects, but the malleability of clay leads to slight variations in individual units. This variation in the standardized units is analyzed by overlaying section drawings of several tiles.

2.A.1) Interpretations of surface markings

Despite recent advances in the technical analysis of archaeological ceramics, there have been relatively few studies of the manufacturing techniques of ceramic roof

²⁰ The descriptions conform to the field manual of the Corinth Excavations, and colors are recorded using the *Munsell Charts*.

tiles.²¹ Few publications have attempted to describe the undecorated surfaces of ancient tiles. Those that discuss the manufacturing of tiles have not methodically described the markings which should be the basis for interpreting the production sequence.

In order to describe and understand surface markings on tiles, they must be classified. Because they exhibit a greater range of treatments than tiles of most later roofing systems, Protocorinthian tiles are a strong basis for developing a relatively complete typology of ancient roof tile markings. However, some finishing techniques such as burnishing, commonplace on later Archaic and Classical tiles, are lacking on Protocorinthian tiles. The formal typology of surface markings is presented in Chapter 9 after the preliminary analysis of the ancient fragments and the replication experiments.

2.B) Experimental replications

Experimental archaeology is the subject of a number of recent theoretical papers.²² Because the experiments include practices that fall short of the rigorous controls demanded by most scientific research, inferences drawn from the experiments must be treated cautiously. Mathieu summarizes earlier discussions about the design and theory of “replicative” or “imitative” experiments, where controlled reenactments of past phenomena are designed both to generate and to test hypotheses. The process results in a superior analogy for interpreting the archaeological record than could be

²¹ Winter summarizes several: Winter 1993, pp. 304-308. The only study of Protocorinthian tiles is Rostoker and Gebhard 1981, considered below. Comments on the manufacturing of sixth-century tiles at other Greek sites include Le Roy 1967, pp. 199-205; Schneider 1991; 1996, pp. 24-42, 55-115; Hübner 1997; Schädler and Schneider 2004, pp. 21-26. Studies of non-Greek archaic tiles include Hostetter 1994; Glendinning 1996b, pp. 29-41; Rystedt 1983, pp. 111-125; C. Wikander 1988, pp. 56-74; Ö. Wikander 1993, pp. 100-139.

²² Ascher 1961a; Coles 1979, pp. 38-48, 160-162; Ingersoll, Yellen, and MacDonald 1977; Mathieu 2002; Tringham 1978.

drawn from ethnographic sources alone. Mathieu separates four scales of replication experiments, stressing the importance of strict controls to assess confidence in the final interpretations. The scale of the Protocorinthian tile experiments undertaken here is “object replication,” where the primary goal is understanding the manufacturing techniques of a particular type of artifact, not the performance characteristics of the artifact during its later use (behavioral replication), the later formation processes in the archaeological record (process replication), or the simulation of an entire system.²³

The experiments in this thesis have attempted to create “full replicas,” where only materials and production techniques likely to have been used to create the original artifacts are selected.²⁴ Of course, some items commonly available in antiquity may be substituted by their modern equivalents without affecting the outcome of an experiment. For example, a rubber basket for gathering clay will serve adequately in place of a wicker one. Other aspects, such as the overland transportation of raw materials, are not worth reproducing in an “authentic” fashion. For example, the information gained by hiring a donkey in lieu of a modern truck will be unreliable in a modern context. In other words, certain elements of a production sequence like the speed of donkey transportation in antiquity are better estimated using ethnographic and historical documentation.²⁵ Because human physiological limits can be reliably estimated as well, the most important variables in this study—the productivity of individual laborers—can be restored accurately.²⁶ A ceramicist was recruited for the replication experiments conducted at Corinth in order to ensure an individual highly

²³ Mathieu 2002, pp. 3-6.

²⁴ Mathieu 2002, pp. 2-3; see also Coles 1979, pp. 46 (items 1 and 2).

²⁵ Arnold 1985; Cotterell and Kamminga 1990.

²⁶ Bleed 2001, pp. 156-159; Coles 1979, pp. 246-247; Saraydar and Shimada 1973; Shimada 1978. Physiological measurements of human and animal labor: Consolazio, Johnson, and Pecora 1963; Cotterell and Kamminga 1990; Drennan 1984; Reyman and Dirks 1985; Durnin and Passmore 1967.

competent in working clay guided the process. The resulting experimental data are valuable analogies for modeling the ancient production environment.

However, the authenticity of the replication environment for Protocorinthian tiles does not by itself guarantee certainty of the test results. The degree of control in fact is relatively low in these “first generation experiments,” where the entirety of the forming and finishing sequence is tested primarily for its overall feasibility.²⁷ Consequently, the certainty of the interpretations derived from the experiments themselves is relatively low, because the tests confirm only that the preliminary hypothesis is possible and do not reject every conceivable alternative. Nevertheless, certain problematic variables such as the sources and shrinkage rates of Corinthian clays have been subjected to more controlled, repeated tests within the framework of the broader analysis.

An important assumption underlies many experimental studies exploring the time and labor costs of ancient production. Modern experimenters must assume they are able to reenact processes at approximately the same speed as ancient craftsmen, so long as all other conditions of the experiment are carefully controlled. This assumption is validated by the “least-effort principle,” which predicts that, within their capabilities, craftsmen tend to work efficiently over the term of a project. Its relevance to ethnographic and archaeological experiments is considered below.

2.B.1) *Interpreting ancient ceramics from an ethnographic perspective*

A replication study of complex ceramic objects benefits from a broad array of analytical techniques. Ceramics confer specific advantages and challenges for object replications. Compared to complex prehistoric activities such as trans-oceanic navigation or house construction which have been tackled by other archaeological

²⁷ Mathieu 2002, pp. 7-8; Tringham 1978, pp. 178-180.

experimenters,²⁸ ceramics—in particular mass-produced objects like tiles—are a relatively narrow and specialized branch of technology. On the other hand, pottery and tiles cannot be created by the short, repetitive operations for activities such as knapping flints or working bone tools.²⁹ These simple operations are favorable to tightly controlled experiments leading to concise conclusions, but this precision is difficult to obtain for an entire ceramic production sequence. Clays are physically and chemically complex and may exhibit dramatic variation in their material properties. The firing introduces further variation by irreversibly altering the original clay minerals. In most cases, the specific ancient clay sources cannot be identified, denying the archaeologist-experimenter any certainty that his or her replicas have been formed from materials with the same performance characteristics as the ancient artifacts. Nevertheless, the material properties of clays and ceramics are well studied in comparison to lapsed technologies like bone and flaked-stone tools. Clays remain an important medium for artistic expression today, not to mention their ubiquity in food service and storage. Thousands of publications about the material properties of ceramic materials indicate their importance to modern engineering. A growing body of archaeological ceramics research focuses on the properties of clays essential to understanding the production processes of roof tiles.³⁰

Ethnographers who documented traditional pottery production over the past century offer an alternative perspective. Explanatory models developed in the context of ceramic ecology and ethnoarchaeology draw analogies between ancient ceramics and the work of living potters.³¹ Although domestic utilitarian pottery production is

²⁸ e.g., see Coles 1979, pp. 49-98, 131-158.

²⁹ e.g., Ascher 1961a; Coles 1979, pp. 162-177; David and Kramer 2001, pp. 151-157; Prasciunas 2007; Semenov 1964.

³⁰ Bronitsky 1989; Jones 1986; Rice 1987; Rye 1981; Shepard 1956.

³¹ Arnold 1985; David and Kramer 2001, pp. 10-11; Franchet 1911; Kramer 1985; Krause 1984, 1985; Matson 1965; Peacock 1982; Takaoğlu 2004.

usually the focus of such investigations, some broad, cross-cultural patterns in ceramic technology have been identified which are useful to apply to the ancient tile-making industry.³² Ethnographic studies of roof tile and brick production in the Mediterranean, Southwest Asia, Northern Europe, and even the Americas—where tile making was introduced by Spanish colonizers—also provide specific parallels for tile making. Factories have now supplanted most of the handmade-tile workshops, but ethnographers documented the tradition before its twentieth-century extinction. However, given the extraordinary size and scale of the Protocorinthian tile system, any opportunity for conducting an authentic “reconstructionist” ethnoarchaeological study ended two thousand years ago when the elaborate architectural terracottas sculpted in Greek workshops were supplanted by much plainer, mass-produced tiles.³³ In other words, the ethnographic record provides insight into the production environment of ancient tiles, but exact parallels for every aspect of the production sequence of Protocorinthian tiles cannot be expected.

2.B.2) *An inferential model for determining the forming and finishing sequence*

A parsimonious explanation for the manufacturing of Protocorinthian tiles may be inferred from the archaeological, experimental, and ethnographic data.³⁴ Because an experimenter attempting to replicate an ancient artifact is confronted theoretically with an unlimited array of potential forming and finishing steps, the problem is applying constraints to narrow these possibilities.³⁵ Besides the limitations inferred from direct observations of the ancient tile fragments themselves, further constraints

³² Arnold 1985, 1993, 2005. On general cross-cultural models, see Coles 1979, p. 246; Gould 1980, pp. 108-112; 1990, pp. 48-51; Yellen 1977, pp. 6-7; Watson 1999, p. 49 (6).

³³ David and Kramer, pp. 10-11, 278; Wylie 1985, especially pp. 105-107.

³⁴ Gould 1980, pp. 46-47; 1990, pp. 47-49, 234-239; Gould and Watson 1982, pp. 367-370; Trigger 1998, pp. 7-14, 17-18, 23-24.

³⁵ e.g., Binford 2001, pp. 32-42; Bleed 2001, pp. 156-157; Carlstein 1982, pp. 25-33; Gould 1980, pp. 109-11; 1990, pp. 3, 13-17, 34-63; Wylie 1985, pp. 88-93, 100-105.

are imposed by the uniform properties of clay and the mechanics of human labor. Cross-cultural patterns in ceramic production may be invoked to narrow the array of likely choices for production steps. The experience of creating replicas reveals other physical constraints and helps drawing analogies to ethnographic parallels. Of course, a modern archaeologist has only a limited capacity to imagine the possible manufacturing techniques known to an ancient craftsman,³⁶ but the variety of information sources gathered in this thesis provides reasonable confidence that the hypothetical forming and finishing sequence does not stray far from the ancient production routine.

Individual production steps may be selected from the array of possibilities on the basis of the following limiting factors:

- (a) fidelity of the replicas to observations of the ancient tiles
- (b) the logic of each step from the perspective of the replication experiments
- (c) the performance characteristics of clays available in the Corinthia
- (d) conformance with ethnographic and archaeological data so far as they are available
- (e) conformance with cross-cultural models of ceramic production

These limits are presented in decreasing order of specificity, meaning that the first limiting factor, direct observations (a), is likely to impose the greatest restrictions on the range of potential production steps. Any ambiguities remaining after considering the first limits may be resolved by stepping through increasingly general expectations from natural and behavioral models. In the cases where primary manufacturing evidence is well preserved among the remains of Protocorinthian tiles, the production step may be specifically defined. Where the evidence is less conclusive, the production step is most constrained by the requirements of labor and ceramic technology, which may be relatively broad and are not always directly

³⁶ Ascher 1961a, pp. 811-812; Trigger 1998, pp. 24, 30-31; Wylie 1985, pp. 85-88.

applicable to roof tiles. For example, although the Protocorinthian tiles are obviously fired clay objects, it is necessary to resort to generalizations from the ethnographic record for many aspects of gathering and firing clay. Consequently, even after stepping from (a) through (e) to consider the primary evidence on tiles, the properties of clays, and the relevant ethnographic models, several explanations will remain equally possible for some production steps.

2.B.3) Estimating construction cost in units of time

Besides testing the hypothesis for the forming and finishing sequence and narrowing the range of production steps, the replication experiments can demonstrate how long it takes to produce tiles. A model can be developed to estimate the labor invested in the whole roof. The cost estimate can only be calculated from a complete production sequence for the tiles, but the inferential model articulated above cannot provide the necessary certainty. The hypothesis for the forming and finishing sequence is no more than a limited range of potential production steps inferred from incomplete archaeological evidence. In order to address these uncertainties, an economic model is adopted here which assumes that the production sequence approaches maximal efficiency within the capabilities of the ancient craftsmen. Under this assumption, the hypothesis can be narrowed to a single most likely sequence of costs to produce a tile, useful for estimating the investment in a roof. Thus from the array of plausible choices for each production step, a single minimum cost is chosen corresponding to the most efficient option.

The most effective currency for expressing these costs is time. This approach to a building problem has innate appeal because of its simplicity and universality. Any construction project in the world may be compared by converting labor and materials into a single time estimate. That is, the cost of materials is counted as the time

required for their extraction. The currency of time has an ancient pedigree. For example, Herodotus describes spectacular numbers of men and quantities of materials invested in the construction of Cheops' pyramid at Giza.³⁷ Many modern studies have grappled with the problem of estimating the investment of time in both ancient architecture and pottery production.³⁸ The currency of craftsman-hours is directly comparable to the extensive body of later Greek and Roman construction contracts. Some contracts document the costs of labor and material for buildings whose remains have been identified, such as the Asklepieion at Epidauros. Furthermore, given the considerable evidence for restoring their forming and finishing sequence, Protocorinthian tiles are good candidates for a reasonably accurate calculation of costs. Timings of manufacturing stages unique to Protocorinthian tiles are known from the replication experiments, but these data are supplemented by ethnographic accounts of the scheduling of common tasks for traditional potters, such as gathering clay. The resulting model summarizes the minimum cost of production for the Old Temple roof in *craftsman-hours*.

2.B.4) Efficiency and the labor estimate

It is not certain that the actual production cost of Protocorinthian tiles was anywhere near this contrived minimum. The goal here is to question whether the minimum cost is a logical model for ancient production. Efficiency is a modern value which does not dominate ethnographic or ancient historical records, and archaeologists have proposed risk minimization as an alternative adaptive strategy.³⁹

³⁷ Hdt. II.124-125.

³⁸ e.g., Adams 2001; Coles 1979, pp. 137-139, 150, 152; DeLaine 1997, pp. 104-107; 2001; Erasmus 1965; Feinman, Upham, and Lightfoot 1981; Hasaki 2002, pp. 277-284; Henrickson and Blackman 1999; Salmon 2001; Saraydar and Shimada 1973; Shawcross 1972, pp. 589-592; Sheehy 1988, pp. 216-221; Shimada 1978; Vossen 1984.

³⁹ Bleed 1986, pp. 738-739; Braun 1983, p. 111; Foley 1985, p. 226.

Cost minimizing is an ideal of modern economics and engineering which can be applied to non-Western, pre-modern societies only with caution. However, this study focuses exclusively on the labor cost of the temple roof rather than connections to the broader economic system of Archaic Corinth, so many controversies about modeling non-Western economies may be bypassed.⁴⁰ More relevant here are archaeological studies that relate prehistoric human adaptive strategies to the efficiency of energy capture from the environment.⁴¹ For example, optimality theory assumes that, similar to other living organisms, humans prefer strategies for specific tasks, such as food procurement, which are efficient.⁴² The behavior models based on this theory compare the costs and benefits of various strategies within an environment. When applied to archaeological data, the hypothetical “optimum” that minimizes cost is expressed as a common currency, which is often energy efficiency,⁴³ although risk-minimizing is a related alternative.⁴⁴ As an ideal adaptive strategy derived from simplified environmental parameters, the optimal state is an untestable assumption, but the specific hypotheses generated by the optimality assumption can be tested by comparison to actual archaeological or ethnographic data.⁴⁵ Besides the predictive success of similar models of animal behavior which encouraged archaeologists to apply the methods to humans in the first place, there are in fact some cases where human adaptive behaviors approach a theoretically derived optimum. For example, ethnoarchaeological studies of prehistoric stone tools indicate that the toolkits carried by these mobile foragers balance utility against weight. The prediction that large tools

⁴⁰ e.g., Carlstein 1982; Earle 1991; Rocha 1996; Schiffer and Skibo 1997.

⁴¹ Shawcross 1972. See also Binford 2001; [1983] 2002, pp. 208-213; Bettinger 2006; Carlstein 1982; Gould 1980, p. 140; Jochim 1979, pp. 90-91; Johnson and Earle 2000, pp. 1-37; Nelson 1991, pp. 58-62, 73-76; Potts 1984, pp. 345-47; Torrence 1983; Yellen 1977, pp. 64-65.

⁴² Broughton and O’Connell 1999; Foley 1985, pp. 226-227; Winterhalder and Kennett 2006; Sheehan 2004; Smith 1979; Winterhalder and Smith 1981.

⁴³ Broughton and O’Connell 1999, p. 154; Foley 1985, pp. 228-229, 233, 238-239; Winterhalder and Kennett 2006, pp. 11-14; Smith 1979.

⁴⁴ Binford 2001, pp. 37-41; Gould 1980, pp. 108-112; Gremillion 2002; Jochim 1979, pp. 83-90.

⁴⁵ Foley 1985, pp. 223, 230-231; Jochim 1979, pp. 101-103.

maximize utility over mass is matched by the preference for heavy, multi-function tools in the archaeological record.⁴⁶ Thus despite the limitations of optimality theory, the principle has valid archaeological applications.⁴⁷

The complexity of pottery production has hindered the development of an equivalent to optimality theory for pottery, yet cost minimizing is a factor considered in many ceramics studies. The “least-effort principle,” discussed below further, has been invoked for modeling the behaviors of potters and the morphology of their products.⁴⁸ Arnold’s “exploitable threshold model”—a consistent pattern among traditional potters of gathering clay within a limited radius of their workshops—can be explained as the result of minimizing energy expenditure. In his global sample of over 100 ethnographically and historically documented communities, potters seldom travel more than 7 km to obtain clays and other raw materials.⁴⁹ However, due to the variability in local customs and ecology, the model does not apply universally, and a significant fraction of Arnold’s sample exceeds the 7-km threshold. Other scholars have attempted to model the efficiency and skill of a potter. The standardization hypothesis predicts that increased specialization of a potter correlates in part to a greater efficiency in production.⁵⁰ Another model developed for ceramics, the “production step measure,” models efficiency indirectly by equating labor cost with the number of processes required to decorate a vessel.⁵¹ Pots themselves exhibit

⁴⁶ Shott 1986:36-45; Torrence 1983; Morrow 1996 (*contra* Kuhn 1994).

⁴⁷ Bleed 1986; Broughton and O’Connell 1999, pp. 154-156; Earle and Preucel 1987, p. 511.

⁴⁸ Braun 1983, pp 111-112; DeBoer 1984, p. 531; Rands 1988; Smith 1985, p. 256.

⁴⁹ Arnold 1985, pp. 32-57; 1993, pp. 200-204; 2005.

⁵⁰ Costin and Hagstrum 1995; Costin 1991, pp. 16-18, 37-39; Davis and Lewis 1985; Frankel 1981, 1988; Hagstrum 1985, 1986; Roux and Corbetta 1989; Roux 2003; Stark 1995; Stark and Hepworth 1982. On the standardization hypothesis in general: Eerkens and Bettinger 2001; Rice 1981, 1984, 1991.

⁵¹ Feinman, Upham, and Lightfoot 1981; Feinman, Kowaleski, and Blanton 1984; Costin and Hagstrum 1995; Hagstrum 1986, 1988.

optimized performance characteristics. For example, cooking pots have fabrics selected to minimize thermal shock from repeated heatings over a kitchen fire.⁵²

Thus, true optimality models for potters remain untested. This does not mean that potters are oblivious to efficiency, but only that rigorously defined optimality models have not been developed to compare to documented behaviors of potters. However, the question is significant for archaeological experiments, in particular when attempting to estimate the organization of labor and the cost of a building project. If a carefully designed replication experiment identifies the minimum labor required for an ancient construction process, how likely is it that ancient craftsmen would have actually approached this minimum? Previous experimental studies have assumed implicitly that ancient craftsmen were efficient and worked consistently over long periods of time, yet rates of failure, variability in working hours, and the motivation of individual craftsmen must also be considered.⁵³

2.B.5) *The Principle of Least Effort and ancient craftsmen*

A provocative statement of energy efficiency is Zipf's Principle of Least Effort,⁵⁴ which has been cited as a model for restoring ancient pottery production and other past human behaviors.⁵⁵ Zipf argues that in large systems with competing demands for time, "an individual minimizes his effort over his future only insofar as he can assess the probabilities of his future."⁵⁶ Thus, the minimum is expressed as an average expenditure of work over time. Instead of insisting on working at a steady rate, craftsmen will undertake a strenuous task occasionally if they believe that by

⁵² Bronitsky and Hamer 1986; Feathers 2006; Klemptner and Johnson 1985, 1986; Rye 1976; Schiffer et al. 1994; Steponaitis 1984; Tite, Kilikoglou, and Vekinis 2001; Tite and Kilikoglou 2002.

⁵³ e.g., see above, notes 37 and 38.

⁵⁴ Zipf 1949. Here the less emphatic "least-effort principle" is preferred to Zipf's all-encompassing formulation of the "Principle of Least Effort."

⁵⁵ Brown 1991, p. 98; Carlstein 1982, pp. 28-32; Johnson 1981; and above, note 48.

⁵⁶ Zipf 1949, p. 341.

doing so they will reduce the overall labor for the job. Like the recent optimality models adopted from behavioral ecology, the least-effort principle presumes only a trend toward an optimally efficient and stable equilibrium without specifying the motivation for the trend. Individuals will deviate from the optimum because of limitations in their predictive abilities, so optima are most apparent with data measured over long periods of time or for large groups.⁵⁷ Zipf made testable predictions from linguistic models that he developed using the Principle of Least Effort, and he marshaled an impressive volume of quantitative linguistic data that seem to match his predictions.⁵⁸ Although his mathematical model has been slightly modified and its interpretation is controversial, the least effort principle remains an effective explanation for the universality of “Zipf’s Law” in rank-frequency plots of human languages.⁵⁹ Nevertheless, Zipf’s economic data have since been demonstrated to be inaccurate,⁶⁰ and his general prediction that efficiency would govern all realms of human behavior must be rejected.⁶¹

The formulation of the least-effort principle is ideal for an economic analysis of an ancient building project. In the linguistic analysis, Zipf developed what is essentially an optimality model for language through an analogy to a craftsman working at the job of verbal communication. Although his model was empirically tested for language rather than an actual construction process, it may be easily adapted to the problem of reconstructing the procedures chosen by an ancient craftsman to manufacture tiles. The least-effort principle predicts that craftsmen will select the

⁵⁷ Zipf 1949, pp. 5-12, 339-343, 543-544.

⁵⁸ Zipf 1949, pp. 19-209; Zipf 1965, especially pp. 263-310.

⁵⁹ Support for least effort models: Bybee and Hopper 2001; Fenk-Oczlon 2001; Ferrer i Cancho and Solé 2003. Alternative explanations: Bailón-Moreno et al. 2005; Montemurro and Zanette 2002; Zanette and Montemurro 2005.

⁶⁰ Zipf 1949, pp. 347-516 is refuted by Eeckhout 2004; Gabaix 1999; Nitsch 2005; Simon 1955.

⁶¹ Binford 1962, pp. 220-221; [1983] 2002, pp. 221-227; Bunge 1996, pp. 366-370; DeBoer 1984; Jochim 1983.

course of action which minimizes effort for a whole job, but only within their predictive abilities. For Zipf, the predictive abilities of the craftsmen are similar to the limits in human decision-making which are considered by optimal foraging models. In other words, it is essential to consider the technical sophistication of craftsmen before determining which production methods are most economical, or which methods might entail excessive risk to the final product. The experimental process of creating “full replicas” of Protocorinthian tiles addresses largely the same problem by physically reenacting as much of the ancient forming and finishing sequence as possible. The archaeological context and ethnographic analogies together, however, are the most powerful tools for reconstructing the array of clay-working techniques available to an ancient craftsman. The analysis of the limiting factors, steps (a) through (e) above, in order to refine the forming and finishing hypothesis contributes to this model of the predictive abilities of an ancient craftsman.

For the language data that give the strongest empirical support to Zipf’s theory, the least-effort principle has a time frame of countless generations to approach an optimal state. However, the first Protocorinthian tiles were fabricated as a batch, probably just for the Old Temple roof at Corinth and in a limited time, so lack of experience making these tiles might have seriously hampered the abilities of the craftsmen to predict the most efficient production sequence.⁶² Risk might override minimizing effort as well. Craftsmen fearful of losing tiles to breakage throughout the production sequence might lavish “excessive” time and care on critical stages. The potential effects of these risk-minimizing behaviors are factored into the calculation of time costs during the following discussion of individual production steps.

I experienced significant time pressure in the field even while replicating only a small batch of Protocorinthian tiles. The first preoccupation was failure. Although

⁶² Also see Keller 2001.

the existence of the ancient specimens themselves demonstrated that identical tiles could somehow be made, my hypothetical sequence was incomplete, untested, and thus prone to catastrophic failure. Neither were my own abilities equal to those of a Corinthian specialist potter, although this doubt was partly assuaged by consulting with an experienced ceramicist competent in building large ceramic sculptures. In other words, the first problem I encountered when creating tiles was minimizing risk, because a successful outcome to the project was more important than efficiency. However, while carrying out the project, my attention soon turned to economizing for time rather than risk. Even while risking the overall success of the experiment, my decisions about how to schedule various production steps and my reactions to unexpected problems during the process usually were intended to save time. In other words, even before successfully completing a single replica tile, the pressure to economize time dominated as long as I believed there was a reasonable chance of success. The sources of time pressure one might imagine in antiquity certainly differed from my own: the limited window of opportunity for conducting the project, the budget, other research responsibilities, or the approaching deadline of an intercontinental flight home. Nevertheless, after overcoming the initial fear of catastrophic failure, an ancient Corinthian craftsman would have been subject to different time pressures.

Although the first job at Corinth likely consisted of the fabrication of a single roof and certainly could not represent a continuous tile-making tradition,⁶³ the craftsmen would have been subject to time pressure. The Old Temple was fitted with approximately 1,500 tiles⁶⁴ and probably had an additional stockpile for later replacements. Each unit must be identical in order to interlock seamlessly with its

⁶³ See below, Chapter 10.

⁶⁴ See below, p. 68f.

neighbors. At an average fired weight of 31 kg per tile, the crew needed to mine, process, form, and fire enough material for about 34 metric tons of tiles, certainly a daunting task for craftsmen who at the time were familiar only with the production of wheelmade pots and larger handmade storage jars. A foray into decision-making models incorporating risk is impossible without more specific data about the ancient craft environment,⁶⁵ but clearly any production step that saved significant time and did not immediately drive failure rates over 10% or 20% would have been preferred at the scale of production demanded by the Old Temple.⁶⁶

Ethnographic studies frequently describe potters who sacrifice quality for speed in order to meet production quotas. Although potters are often characterized as conservative or even superstitious about introducing change into successful practices, ethnographic accounts of potters who are economically dependent on their craft suggest efficiency is also paramount. Hampe and Winter's journal of their visits to Greek pottery workshops includes a dramatic encounter with a group of potters from Thrapsano who were working hurriedly to make up for a missing crew member.⁶⁷ They worked overtime and lost half of a large batch of storage jars by rushing the drying and firing through rainy weather. More generally, many Mediterranean potters stressed by falling prices after the Second World War sacrificed quality to increase their quantity of output. Established workshops driven by competition often set daily production quotas for wheel throwers, as documented at Spanish potting villages and elsewhere.⁶⁸ Potters in small villages in Mexico expressed a desire to improve kiln technology rather than displaying an inherent conservatism. Although a few experimented with alternatives, most of these potters were hindered primarily by

⁶⁵ e.g., Johnson and Earle 2000, pp. 29-32; Gould 1980; Rands 1988; Torrence 1983, pp. 17-19; van der Leeuw 1989; Winterhalder and Kennett 2006, pp. 11-13.

⁶⁶ Typical failure rates at pottery workshops are 5-10%; Hasaki 2002, p. 111.

⁶⁷ Hampe and Winter 1962, pp. 20-21, 31-40.

⁶⁸ e.g., Vossen 1984.

limitations in their predictive abilities—they were inadequately informed about the success rates and designs for other kilns.⁶⁹

Quality is another factor which must be considered. Individual tiles were carefully made, and, at its time, the Old Temple was the largest and most impressive building in Corinth. Clearly the initial design of the Protocorinthian tiles was ambitious, and the drive in the construction of a monumental temple was to push the limits of creativity. In essence, there were two contrasting incentives in the production sequence: one toward the highest degree of craftsmanship attainable per tile (time-expending pressure), and another toward efficiency in order to complete the project (time-saving pressure). The idea of building a colossal monument was tempered by a realistic appraisal of the available resources for the job. The overall task of designing, fabricating, and installing what was during its time a highly experimental roofing system was limited by the available labor, skills, and resources. Thus, the efficiency discussed in this situation is not a single-variable optimum, such as the minimum time needed to roof a certain area using ceramic units, but rather Corinthian specialists would have gauged the project against their known capabilities. The conception of the Protocorinthian roof, whose purpose was to honor the gods, was in no way subject to efficiency or time minimization. The implementation of this design with a real forming and finishing sequence, however, would have been efficient.

In conclusion, it is plausible that Protocorinthian tile makers would have thought carefully about the efficiency of their production techniques. Confronted with a job to create 1,500 interlocking tiles, they must have developed a single production sequence by experimenting with a few mockups. As a prototype, the full tile system would not be optimized effectively, and indeed the Protocorinthian tile system was

⁶⁹ Papousek 1989.

extremely inefficient in comparison to later roofing systems.⁷⁰ In other words, the least-effort principle suggests that only the most familiar production steps are likely to be executed efficiently.⁷¹ Many processes known from the existing pottery industry, such as techniques for preparing paste or firing a kiln, could be adopted directly without much experimentation. Other steps in the forming and finishing of Protocorinthian tiles would have required more innovation, although, after concluding the replication experiments, these techniques appear so simple that the ancient artisans certainly would have had little difficulty carrying them out efficiently. Consequently, the seventh-century craftsmen had the skills and motivation to create and execute a relatively efficient production sequence that would have matched or slightly bettered the timings from the modern replication experiments.

2.B.6) *Least effort, time, and production organization*

Thus far, the discussion has concerned the individual craftsman working alone, which is unlikely to have been the ancient practice. Creating roof tiles would have involved multiple craftsmen, potentially improving the average productivity of the individual participants.⁷² As will be demonstrated later, a hierarchy of individuals with different levels of experience, skills, and specializations likely participated in different sets of tasks along the manufacturing sequence.⁷³ The work of individual craftsmen in a tile-making team cannot always be reconstructed, but the general currency of labor cost is an effective substitute for this uncertainty. In other words, as long as each

⁷⁰ Ö. Wikander 1988, pp. 205, 206-207; 1992, pp. 151-156. Also see below, Chapter 10,

⁷¹ Some ancient fragments of tiles exhibit evidence of mistakes and corrections. Isolated corrections can be ignored in the overall discussion of efficiency, but some corrections are so common that they are integrated into the general manufacturing hypothesis.

⁷² For examples of increased efficiency among cooperating foragers, see Gould 1980, p. 94-97.

⁷³ Rice 1991, p. 263.

craftsman works efficiently, it may be assumed that the labor for the whole job is distributed evenly among crew members.⁷⁴

The replication experiments also clarify the minimum number of individuals who are required to perform a production step and who are able to perform a production step most efficiently. For example, it may have been possible for one craftsman to lift a heavy eaves tile from a mold by himself, but the job could have been handled more efficiently with an assistant. By definition, any production step is more efficient for a pair of workers if the time for executing the task together is more than halved. At a certain point, however, adding extra assistants reduces the overall efficiency of the job by drawing away laborers who could work elsewhere more productively. Following the least-effort principle, the most efficient teaming of members for every production step is that which achieves the minimum total labor time for the group. When applied to the entire production sequence, this analysis predicts the *minimum effective crew*, the number of craftsmen that will minimize energy expenditure over the course of the job by avoiding scheduling conflicts. The minimum crew is the basis for estimating craftsman-hours and the smallest possible subdivisions of a team. A larger crew could have finished the job more quickly but would have sacrificed efficiency.

⁷⁴ Coles 1979, pp. 138-140, 150-152; Foley 1985, p. 236; Gremillion 2002, p. 147; Smith 1979, p. 70.

CHAPTER 3: INTRODUCTION TO THE PROTOCOLINTHIAN ROOFING SYSTEM

The Protocorinthian tile system is generally believed to be the earliest in post-Mycenaean Greece.⁷⁵ First, this chapter reviews the history of excavations of Protocorinthian tiles at Corinth, Isthmia, Delphi, and Perachora. Next, the evidence for prehistoric tiled roofs is reassessed. A description of the components of the Protocorinthian tile system follows. Finally, an estimate of the number of tiles on the roofs of the temples at Corinth and Isthmia is presented.

3.A.1) *Corinth: excavations of the Old Temple*

Saul Weinberg excavated the first traces of a predecessor to the Archaic Temple of Apollo at Corinth in 1938.⁷⁶ Because his primary objective was to explore prehistoric levels on Temple Hill and find evidence for the construction date of the sixth-century temple,⁷⁷ he described the blocks and tiles of the Old Temple only briefly. Mary C. Roebuck excavated Temple Hill in 1954 to find more material from the early roof.⁷⁸ Besides identifying the regular, hip, and ridge combination tiles, she recovered blocks, mud bricks, and charred pieces of wood from the destruction of the building in the sixth century B.C. The debris had been dumped into the bed of an early Archaic roadway to expand the dimensions of the terrace, making room for the large peripteral Apollo Temple that stands today.

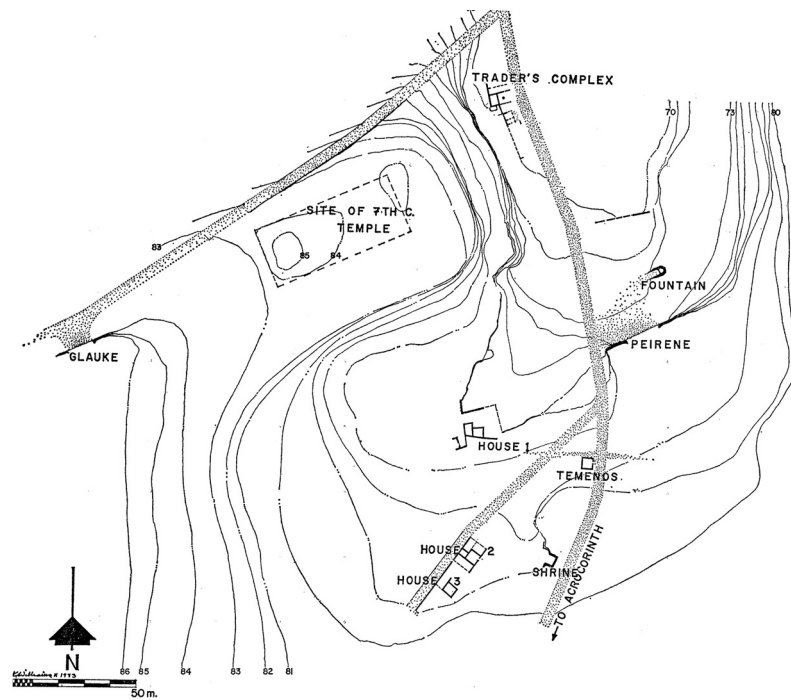
Henry S. Robinson and Charles K. Williams, II, excavated Temple Hill from 1968 to 1979, and Robinson published a report of the first five seasons through 1972

⁷⁵ Williams 1980, p. 346; Robinson 1984, pp. 55-57; Heiden 1987; Roebuck 1990, p. 49; Ö. Wikander 1990, 1992; Winter 1993, p. 12; Glendinning 1996b, p. 184; Winter 2000, p. 256; Gebhard 2001, pp. 54-55; Aversa 2002, pp. 233, 248; Rhodes 2003, p. 87.

⁷⁶ Weinberg 1939a, p. 595 and p. 593 figure 3.

⁷⁷ Weinberg 1937, pp. 488-492; 1939a; 1939b.

⁷⁸ Roebuck 1955, especially pp. 156-157 and plate 62.



**Figure 3.1 Plan of Temple Hill in the early sixth century B.C.
(Robinson 1976a, p. 214 figure 5)**

(Figure 3.1).⁷⁹ One stratum 8-11 m north of the sixth-century temple foundations contained chips of oolitic limestone (poros) probably cut from the Old Temple's blocks.⁸⁰ Robinson first dated the temple to ca. 700 B.C. but subsequently lowered the date to 680 B.C. based on the Early Protocorinthian pottery in the deposit.⁸¹ However, Middle Protocorinthian sherds are also present in the context, so the *terminus post quem* for the construction of the temple should be 680-650 B.C.⁸² Because any stone cutting in the area could produce the working chip layer, the stratum cannot be associated with the Old Temple with certainty. The majority of the poros blocks and

⁷⁹ Robinson 1976a; also see Robinson 1976b.

⁸⁰ Trench V: Robinson 1976a, pp. 211-212 and 211 note 26: Corinth Pottery lots 6420, 6421, 6426.

⁸¹ Robinson draws attention to a well-preserved Early Protocorinthian oinochoe in the stratum: Robinson 1976a, pp. 212, 212 note 27, 234-235, plate 54c. He lowered the date to ca. 680 BC in later publications, apparently retaining the Early Protocorinthian pottery date: Robinson 1984, p. 57 and note 5; 1986, p. 45.

⁸² Although Robinson claims that Keith DeVries originally dated the context to 720 – 700 BC, DeVries recently explained to me that he had been misquoted (pers. comm. 2005). He identified Middle Protocorinthian sherds. The lower date is corroborated by Salmon, who reexamined the context material: Salmon 1984, pp. 59-62, especially p. 60 note 18. Winter accepts Salmon's assessment and dates the roof to 675-650 BC: Winter 1993, p. 12 note 4.

tiles had been dumped along the north side of the terrace into the Archaic roadway. The debris included pottery of the late Middle Corinthian and early Late Corinthian periods, indicating the temple was destroyed during the 560s B.C.⁸³

Robinson describes some blocks and tiles in the report.⁸⁴ He reconstructs an aperipteral cella decorated with panels of painted plaster. The panels were framed by a half-timbered wall comparable to Broneer's restoration of the Archaic temple at Isthmia (see below). The campaigns of Robinson and Williams recovered the majority of the Protocorinthian tiles, altogether weighing about 4,300 kg.⁸⁵ Including two tiles from the Weinberg and Roebuck excavations, a total of six tiles had been dropped intact onto the Archaic road.⁸⁶ Two eaves, one ridge, and three regular tiles have now been mended almost complete.⁸⁷ Besides the tiles from the excavations, one ridge tile found inside the Lechaion Road Basilica to the east of Temple Hill must have belonged to the Old Temple roof.⁸⁸

Besides the many preliminary analyses, most of the tiles remain unpublished. While preparing a monograph on the early temple that was never completed, Robinson published two brief articles describing the Protocorinthian roof and Archaic Corinthian tile production in general.⁸⁹ Winter examined the tiles and published inventory numbers and photographs of several fragments for her description of the Protocorinthian tile system.⁹⁰ Many other articles discuss the roof.⁹¹

⁸³ Robinson 1976a, pp. 216-217, 216 note 33.

⁸⁴ Robinson 1976a, pp. 224-235.

⁸⁵ Robinson 1976a, pp. 231-235. For the weight, see Robinson 1984, p. 59.

⁸⁶ Robinson 1976, pls. 50a-b, 52a-b.

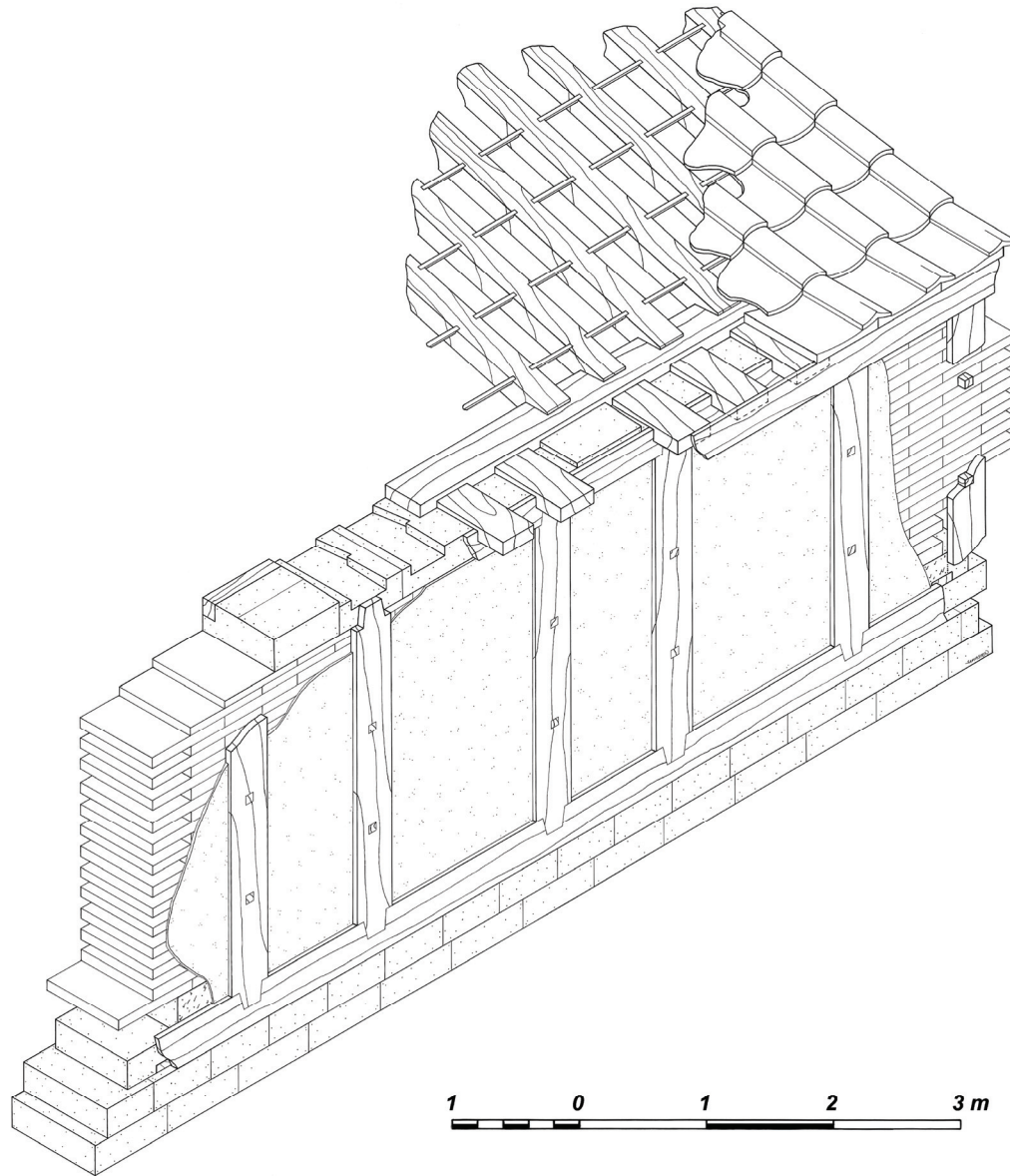
⁸⁷ Regular tiles: FP 155, FT 210, FT 224; eaves: FT 209, FT 211; ridge: FC 31.

⁸⁸ i.e., FR 117, which has been published as a stray find from a later Archaic roof: Winter 1993, p. 85, notes 173-174, table 4.2, pl. 30. However, the fabric and shape of the piece are characteristic of the Old Temple roof, and the findspot is just below Temple Hill to the east.

⁸⁹ Robinson 1984, 1986.

⁹⁰ Winter 1993, pp. 12-16, 317-318.

⁹¹ e.g., Aversa 2002, pp. 236, 248; Billot 1990, pp. 111-113, 121-122; Cooper 1989, pp. 19-32; Heiden 1987, pp. 17-27; Roebuck 1990; Schwandner 1990; Skoog 1998, pp. 21-26; Ö. Wikander 1988, p. 205; 1990; 1992, pp. 151-156; Williams 1978; 1990; 1999; 2002.



**Figure 3.2 The construction system of the Old Temple at Corinth
(Rhodes 2003, p. 89 figure 6.10)**

Robin F. Rhodes is preparing the Old Temple for a publication which will include a new reconstruction of the system of blocks and tiles.⁹² He reconstructs a half-timbered wall. At the cornice, a course of blocks has beddings cut for transverse timbers that would have supported the eaves tiles, which projected from the wall

⁹² Rhodes 1984, pp. 98-102; 1987; 2003. Since 1999, I have studied the remains of the Old Temple as a member of the Greek Architecture Project at Corinth, directed by Rhodes.

(Figure 3.2). These “secondary cornice blocks” with timber beddings alternate with “primary cornice blocks,” which have no transverse cuttings. A shelf at the back of the primary supports would have anchored rafters, and, given the ratio of primary to secondary cornice blocks, every fifth transverse timber would have been omitted to make room for a primary support (Figure 3.2).

3.A.2) Isthmia: excavations of the Archaic Temple of Poseidon

From 1952 to 1961, Oscar Broneer excavated the sanctuary of Poseidon at Isthmia, located about 11 km to the east of Corinth.⁹³ The Classical temple was preceded by an Archaic building identified by masses of burned debris discarded into a nearby roadway, as at Corinth.⁹⁴ Although he identified some traces of Archaic foundations, Broneer’s strongest evidence for the date of the structure is a marble perirrhanterion of the mid-seventh century B.C. He restored it on a base inside the east pteron of the temple. In his reconstruction, the basin provides a *terminus ante quem* for the temple’s construction because he believed it unlikely that the colonnade and walls would have been raised around the basin.⁹⁵ In the final publication, Broneer described most types of tiles from the roof, cataloging 27 tiles and classifying 39 more inventoried pieces out of the thousands excavated.⁹⁶

Elizabeth R. Gebhard and Frederick P. Hemans directed new excavations on the site in 1989.⁹⁷ Although they recovered few fragments of Protocorinthian tiles, they isolated several Archaic strata that indicate a date for the building.⁹⁸ Stone

⁹³ Broneer 1953; 1955; 1958; 1959; 1962; 1971; 1976.

⁹⁴ Broneer 1953, pp. 185, 191; 1955, pp. 111-112, 128-129; 1958, pp. 2-3, 24-27; 1959, pp. 300-301, 303-305; 1962, pp. 21-22; 1971, pp. 3, 40, pl. 12c.

⁹⁵ Broneer 1958, pp. 24-27; 1971, p. 3 note 11 and p. 55. The basin might have been moved to the porch from another location.

⁹⁶ Broneer 1971, pp. 40-53.

⁹⁷ Gebhard and Hemans 1992; 1998.

⁹⁸ Gebhard 2001, p. 59 note 102.

robbers had removed blocks from the foundation trenches associated with the Archaic temple in 470-450 B.C., the period of its destruction by fire.⁹⁹ The excavations detected three surfaces within the area of the foundations which may originally have been floors for the Archaic temple.¹⁰⁰ The lowest contained Middle Protocorinthian pottery, and the upper two were laid in the second half of the sixth century B.C. The earliest floor lies over a hard, almost sterile deposit packed with working chips of poros. The working chips and floor may be associated with the construction and first floor of the Archaic temple. The *terminus post quem* of 680-650 B.C. for the packing of the floor indicates the construction of the Isthmia temple was probably contemporary with the Old Temple at Corinth.

Broneer recognized the fundamental similarities of the Archaic tiles at Corinth and Isthmia. He ascribed both roofs to a single Corinthian factory.¹⁰¹ Several features suggest that the Isthmia temple post-dated the Corinth temple. The greatest difference in the tiles is a triangular wedge added near the front edge of the eaves pan at Isthmia, which is generally accepted as a sign of sophistication and, hence, a later date.¹⁰² Billot alone has argued that the Isthmia roof preceded the Corinth roof.¹⁰³ Several technical innovations in the blocks at Isthmia are stronger evidence for dating the Isthmia temple later.¹⁰⁴ New technical evidence that the Isthmia roofing system was a refinement on the prototype of the Old Temple will be presented in Chapter 9.

⁹⁹ Gebhard and Hemans 1992, pp. 25-34; 1998, pp. 1, 8-10, 12-14.

¹⁰⁰ Gebhard and Hemans 1992, pp. 34-40.

¹⁰¹ Broneer 1971, pp. 50, 49 note 40.

¹⁰² Broneer 1976, p. 43; Cooper 1989, pp. 26-28; Gebhard 2001, p. 56; Heiden 1987, p. 20; Rhodes 1984, p. 105; Robinson 1976a, p. 231; Robinson 1976b, p. 247, note 9; Winter 1993, p. 17. The wedge appears to be decorative, although Williams noted that it might have slowed the force of water that would have tended to concentrate at the center of the pan: William 1978, p. 347.

¹⁰³ Billot 1990, pp. 111-113, 121-122. She distinguishes the cover profiles of the Corinth and Isthmia eaves tiles and argues that the Isthmia tiles' design appears to be the earlier of the two. This argument is invalid because the eaves covers at the two sites are identical.

¹⁰⁴ Rhodes 1984, pp. 98-99, 105; 2003, p. 92. Following the terminology of Rhodes 2003, the innovations of the Isthmia temple are: dovetailed rather than straight-sided plug cuttings for anchoring the half timbering; a more regular system of dovetailed transverse cuttings in the secondary cornice

3.A.3) *Protocorinthian tiles from unidentified buildings*

Le Roy catalogued 21 tiles as Protocorinthian in his study of the architectural terracottas from Delphi, although three are in fact later Archaic types.¹⁰⁵ He divided them into four series by fabric, although only two or three roofs may be represented.¹⁰⁶ The tiles were found in secondary contexts—on the surface of the site, among debris of the “Grand Fouille,” mixed with material below the Lesche of the Knidians, in the vicinity of the Daochos monument, and below the Treasury of the Athenians. Le Roy tentatively assigned dates in the second and final thirds of the seventh century B.C.¹⁰⁷ Because Protocorinthian tiles roofed the major temples at Corinth and Isthmia, he suggested that the pre-Alkmaionid Temple of Apollo at Delphi may have had such a roof. Some of Delphi’s Protocorinthian tiles may also have belonged to a seventh-century Treasury of Kypselos.¹⁰⁸ Another Protocorinthian ridge tile has been excavated recently but is not yet published.¹⁰⁹

Only three other fragments of Protocorinthian tiles are presently stored in the Corinth Museum. Two fragments of regular or eaves combination tiles from the sanctuary of Hera at Perachora have been inventoried.¹¹⁰ However, more fragments of Protocorinthian tiles were noted at the site in 1937 and 1978, and others reportedly are held in the National Museum in Athens.¹¹¹ A fragment of a regular or eaves

blocks; and the addition of a projecting drip moulding to the primary cornice blocks at Isthmia (Broneer’s Group 10 blocks), which anticipate a Doric geison. See below, note 113.

¹⁰⁵ Le Roy 1967, pp. 21-28. I have reclassified his AR 18 (Delphi museum inv. 21640), P 25 (inv. 21660), and P 26 (apparently inv. 22126) as sixth-century tiles.

¹⁰⁶ Le Roy 1967, p. 24.

¹⁰⁷ Le Roy 1967, p. 26; followed by Winter 1993, p. 17.

¹⁰⁸ Gebhard 2001, p. 57; Le Roy 1967, p. 39; Partida 2000, pp. 173-184; Rhodes 1984, p. 134; 2003, p. 93; Robinson 1976a, p. 231 note 93; 1984, p. 55.

¹⁰⁹ Jean-Marc Luce and Marie-François Billot (pers. comm. 2005); the fragment will be published in Luce (in press).

¹¹⁰ i.e., FC 102 and FC 103: Heiden 1987, p. 21 and p. 202 note 26; Rhodes 1984, p. 134; 2003, p. 93, note 22; Robinson 1976b, p. 247 note 9; 1984, p. 55 note 1; Roebuck 1955, pp. 156-157; Winter 1993, p. 17. The two fragments are of regular or eaves combination tiles; a hip tile from Perachora photographed by Rhodes and mentioned by others has a gabled cover, which excludes it from the Protocorinthian system: Rhodes 2003, p. 93 figure 6.15.

¹¹¹ Gebhard 2001, p. 56 note 82; Roebuck 1990, p. 49 note 6.

combination tile was excavated at the Sanctuary of Demeter and Kore.¹¹² These tiles must have belonged to seventh-century buildings at the two sanctuaries.

3.A.4) Chronology of the Protocorinthian roofing system

Despite the paucity of context evidence for dating the Old Temple at Corinth and the Temple of Poseidon at Isthmia, it is clear that the Corinth temple was completed before the Isthmia project was begun. Neither building can be dated directly from foundation deposits, but the presence of working chip layers at both sites associated with Middle Protocorinthian pottery (at Isthmia, in the floor packed immediately above the chip layer) suggests that both buildings were under construction between 680 and 650 B.C. The architectural features of the buildings—such as the large terracotta tiles, the dressed masonry, and the development of an early form of geison at Isthmia¹¹³—are sophistications shared with later seventh-century architecture. Because the contexts at both sites suggest only a *terminus post quem*, a date near the mid-seventh century B.C. is preferable (i.e., ca. 660-650 B.C.). The other Protocorinthian tiles from Corinth, Perachora, and Delphi cannot be reliably associated with any building. Generally it is assumed that the system was invented for the temples at Corinth and Isthmia and later spread to the other sites. If the Old Temple was built in the mid-seventh century B.C., the other tiles would have been produced in the second half of the century.

¹¹² Bookidis and Stroud 1997, pp. 54, 465-466 no. 68 (FC 105); Rhodes 2003, p. 93 note 24.

¹¹³ Group 10 blocks: Broneer 1971, pp. 30-31, 36-38, 55; Rhodes 1984, pp. 62-63, 82-91, 135-151; 1987a. Except an Archaic temple from Mycenae dated 625-600 BC, all other geisa are assigned to Greek buildings of the sixth century or later: Klein 1991, pp. 151-159, 168-169; 1998, pp. 340, 342-343 table 1. The Isthmia stone geison is the isolated example of the first half or middle of the seventh century BC. Instead, with the exception of the Corinth, Sicily, and Magna Graecia, terracotta geison tiles are typical of many regional styles: Winter 1993.

3.B) Prehistoric antecedents to the Protocorinthian tile system

The first fired-clay roof tiles appeared in the Early Helladic period. Best known is the House of Tiles at Lerna, but similar tiles have been found in earlier contexts and at several sites in the Peloponnese, Aegina, and Boiotia.¹¹⁴ Unlike traditional Mediterranean roof tiles, the Early Helladic system has no covers or pans. Instead, the tiles are flat and irregular.

The manufacturing process was consistent. Craftsmen trod sheets of clay spread out on a sandy surface, sometimes leaving behind footprints, and they cut individual tiles out with a knife.¹¹⁵ The edges of the cuts are ragged, and the overall dimensions of the tiles vary considerably. The average length and width is 26.5 x 21.7 cm, much smaller than traditional pan tiles. The roofing system of the House of Tiles has been restored (Figure 3.3). Red clay was spread over a reed mat supported by purlins, and schist slabs were placed at the eaves.¹¹⁶ The tiles were laid at no consistent angle in a thick bedding of white plaster, and the plastering was so thick that the tiles did not contact one another. Overlap was high, from half to two-thirds of the width of the tile going up the slope of the roof.

The haphazard EH roofing system resembles shingling more than later tile systems. In fact, schist slabs lined the eaves of the roof of the House of Tiles, and other buildings from the period were roofed entirely in schist. Rather than functioning as an independently conceived roofing system, the ceramic tiles appear to have substituted for such schist-slab roofs.¹¹⁷ The fired ceramic slabs protect the lower layers of bedding from rainfall, but the functional similarity to later Mediterranean

¹¹⁴ Lerna: Wiencke 2000, pp. 197-201, 253-274, 296, 306-307, figs. I.102b, I.104a, b. An early roof from Phase C at Lerna preceded the House of Tiles. Other Early Helladic tiled buildings: Pullen 1986; Runnels, Pullen, and Langdon 1995, pp. 38-39; Winter 1993, pp. 8-9.

¹¹⁵ Wiencke 2000, pp. 197-198, 253-254; Frödin and Persson 1938, p. 233 and fig. 170.

¹¹⁶ Wiencke 2000, pp. 254-255, 296.

¹¹⁷ Also see Ö. Wikander 1988, p. 204.

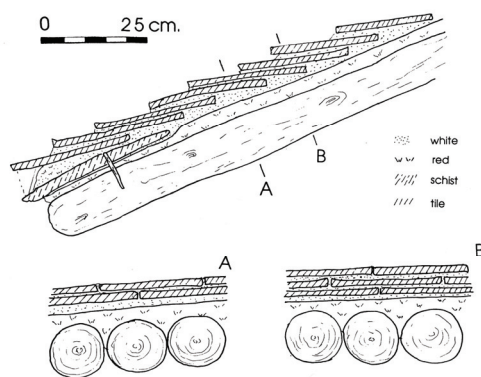


Figure 3.3 Restored roof of the House of Tiles
(Wiencke p. 307, fig. I.104b)

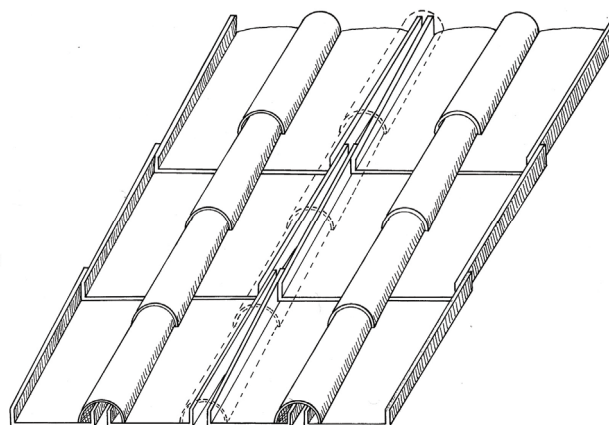


Figure 3.4 The conjectural Mycenaean "hybrid" roofing system
(Iakovides 1998, p. 132 fig. 57)

tiles ends there. The Early Helladic tiles have no devices to interlock with one another or fasten to the woodwork. After the large distribution centers that they roofed were no longer built, the system vanished. No tiles from the Middle Helladic period have been found.¹¹⁸ Consequently, the Early Helladic roofs cannot have developed into Archaic tile systems.

3.B.1) *Roof tiles in the Late Helladic period*

The existence of Mycenaean roof tiles has sparked controversy since 1886, when Dörpfeld's announcement that Tiryns had only flat roofs was immediately contested.¹¹⁹ Objects resembling the covers and pans of later roof-tile systems have been excavated from many Late Helladic sites, and the recent debate has centered on their function (Figure 3.4).¹²⁰ Rounded covers or flat pans have been found in LH III

¹¹⁸ Although Winter classifies tiles from Berbati as Middle Helladic, this is probably an error: see below, note 137.

¹¹⁹ Schliemann 1885, pp. 225, 248-249, 282, 310-313; for a review of the debate, see Iakovides 1990, pp. 147-152. More recently, also see Darcque 2005, pp. 80, 124-126; Küpper 1996, pp. 104-105; Walberg 2007, p. 65.

¹²⁰ The shape of the Mycenaean objects is so close to cover and pan tiles of the hybrid system that I will call them covers and pans without necessarily implying that they were used as roof tiles.

contexts—the majority LH III B1 and B2—at Mycenae, Chania, Berbati, Tiryns, Midea, Chalandritsa, Athens, Thebes, and Gla.¹²¹

The pans and covers are relatively consistent at these sites.¹²² The pans are flat slabs, approximately 40 x 50 cm and 1.3 to 2.5 cm thick. The sides turn up into a pair of rims that are 4.0 to 6.0 cm high. The pans taper from the back to the front in order that the front edge of the pan can fit between the rims at the back of the pan below (Figure 3.4). The overall dimensions are highly variable, in part because the pans are handmade. A coarse sheet of clay tempered with stones or chaff was packed over a flat surface, and the rims were raised by hand. The covers are less common. The clay is finer than that of the pans because covers were thrown on the wheel. A wheelmade cylinder was later cut in half along its length to produce two covers. The covers taper slightly to fit inside the wider front edge of the tile above.

The controversy over the original function of these objects has arisen from an apparent contradiction in the evidence.¹²³ On the one hand is the form. The Mycenaean covers and pans resemble roof tiles from later periods, suggesting that they, too, were used on roofs. The pans resemble those of the Archaic Etruscan and Anatolian tile systems. Although wheelmade, the semi-cylindrical covers superficially resemble the molded covers from later Etruscan or Laconian roofs. The Mycenaean covers are narrow but just large enough to fit over the rims of two adjacent pans.¹²⁴ Thus, the covers and pans are able to fit together as a “hybrid” roofing system (above, Figure 3.4).¹²⁵ On the other hand, contradicting the interpretation by form is the

¹²¹ See Iakovides 1990, pp. 152-154; Küpper 1996, p. 105; Winter 1993, p. 10.

¹²² Iakovides 1990, pp. 155-156; 2001, p. 112; Küpper 1996, pp. 106-109, 134-136, 108 tables 1-4, figs. 111-127, 210-216, pls. 51-52.

¹²³ For a review of the debate, see Iakovides 1990.

¹²⁴ See, e.g., Küpper 1996, pp. 109, 266-270 figs. 211-216; Walberg 1998, pl. 141.

¹²⁵ e.g., Åkerström 1941; Iakovides 1990, 2001; Küpper 1996, pp. 105-110; Winter 1993, p. 11.

scarcity of Mycenaean tiles. Such tiles have not been identified at many sites, and the sites with tiles have yielded relatively few fragments.

In 1945, Carl W. Blegen articulated the scarcity objection.¹²⁶ He observed that hundreds or even thousands of fallen tile fragments usually blanket collapsed buildings that had tiled roofs. Tiles do not quickly disintegrate because the fired clay must be extremely durable in order to withstand rainfall, and broken tiles from a destroyed roof have little value to scavengers.¹²⁷ However, almost sixty years after Dörpfeld reported the lack of tiles at Tiryns, Blegen could state that no archaeologist had encountered convincing evidence for a collapsed tiled roof in a Late Helladic context.¹²⁸ Blegen instead proposed that the few pans identified at his time had originally been used as drains.¹²⁹

Blegen's drain-tile theory went largely unchallenged until Spyros E. Iakovidis revived the argument by form.¹³⁰ Blegen had been aware of only a few Mycenaean cover tiles and did not discuss them at length. However, since Blegen's time, Mycenaean tiles have been identified at several sites, and both covers and pans have been excavated together.¹³¹ In particular, excavations at Gla recovered many more tiles, including a large cache of cover tiles (see below, Figure 3.5). In opposition to Blegen, Iakovidis argues that the pan tiles could not have been used as drains because the rims were too low to keep water from spilling over the borders. He also rejects the possibility that the covers could have been used upside-down as drains. He proposes

¹²⁶ Blegen 1945, pp. 37, 39-40; seconded by Darcque 2005, pp. 124, 128; Ö. Wikander 1988, pp. 204-205; Winter 1993, p. 11.

¹²⁷ Tile fragments can be built into rubble walls or ground into grog for tempering new clay. However, walls built from reused tiles are not known from Mycenaean or Early Iron Age Greece, and grog cannot be proven to come from tiles rather than another type of ceramic object. Intact tiles, of course, are reused whenever possible.

¹²⁸ On Blegen's convincing dismissal of evidence for roof tiles at Malthi (Dorion), see below, note 144.

¹²⁹ Blegen 1945, pp. 40-41, supported by Shear 1968, pp. 335-336, 434-435.

¹³⁰ Iakovidis 1990; 1998, pp. 249-250; 2001, pp. 135-137; for earlier brief discussions of the topic, see Iakovidis 1990, p. 148 note 25.

¹³¹ Iakovidis 1990, pp. 152-154, 154 fig. 9.

instead that the covers and pans were components of a Mycenaean hybrid roofing system. To explain the scarcity of the tiles, he suggests that Mycenaeans reused most of their tiles, or else careless excavators mistook fragments of tiles for larnakes, storage jars, or later intrusions.¹³² Iakovides concludes that all Mycenaean buildings had low-pitched, tiled roofs.¹³³

Although the identification of the excavated Mycenaean covers and pans as roof tiles has been generally accepted, Iakovides' assertion that Mycenaeans did not build flat roofs in the fourteenth and thirteenth centuries B.C. has been received skeptically.¹³⁴ The fact that the form of Mycenaean roofs has remained in doubt for so long suggests that tiled roofs were at best exceptional. Furthermore, any interpretation of Mycenaean covers and pans as roofing material has a high burden of proof. It will be argued here that the existing evidence cannot support the roof-tile hypothesis.

3.B.2) *Tiles from Late Helladic contexts*

The finds of Mycenaean tiles are few enough that they may be briefly reviewed. A small number of fragments that resemble pans has been found in Thebes, Athens, Berbati, Tiryns, Chania, and Chalandritsa. Keramopoulos found at least 13 rim fragments, perhaps from pan tiles, inside six tombs at Thebes.¹³⁵ Broneer identified as pans two fragments of flat plaques with thickened rims from the underground Mycenaean water system on the Athenian Acropolis.¹³⁶ Five flat, handmade pans of widely varying dimensions were found lining two graves in a

¹³² Iakovides 1990, p. 155.

¹³³ Stating that it is "highly improbable" that flat roofs were built: Iakovides 1990, p. 160.

¹³⁴ e.g., Darque 2005, pp. 124, 128; Walberg 2007, pp. 65-66; Winter 1993, p. 11.

¹³⁵ Keramopoulos 1917, pp. 75-77; also see Blegen 1945, p. 38.

¹³⁶ Broneer 1939, p. 409 and pp. 408-409 figs. 90-91b,c; also see Blegen 1945, p. 39. The profiles of the two fragments differ from other Mycenaean pans.

potters' workshop at Berbati.¹³⁷ Fourteen fragments from pan tiles and two pieces of wheelmade cylinders were found elsewhere at Berbati. However, the cylinders cannot be identified as covers with certainty because they preserve no rims.¹³⁸ Tiles are reported inside Late Helladic buildings at Tiryns, but only a few pan tiles are clearly identified in the publications. The architectural debris removed from Building II includes one well-preserved pan, and a small number of other fragments described as covers and pans are not illustrated.¹³⁹ Two small fragments of plaques with raised rims were found among debris of mud bricks and painted plaster over Building III.¹⁴⁰ Some fragments of plaques with rims 7-10 cm high were found in room 121 of Building VI.¹⁴¹ Among the burned debris of two buildings at Chania, 3 km southeast of Mycenae, were three well-preserved pans and one irregular wheelmade cylinder, which, like those from Berbati, lacks a preserved rim.¹⁴² Pan tiles are reported from the late Mycenaean settlement at Chalandritsa.¹⁴³ Although Iakovides includes Malthi (Dorion) in his register of Mycenaean tiles, no convincing evidence of either covers or pans was excavated at the site.¹⁴⁴ On their own, these isolated finds of pans cannot be interpreted as evidence for collapsed tiled roofs.

¹³⁷ Åkerström 1941; Ö. Wikander 1988, p. 204; Winter 1993, pp. 9-10. Winter classifies these tiles as Middle Helladic, although Åkerström, whom she alone cites, dated the graves by the presence of Mycenaean sherds: Åkerström 1941, pp. 166, 168.

¹³⁸ Åkerström 1941, pp. 168-170 and fig. 10. The "cover" tiles have an unusually large diameter and are more convincingly restored as chimney pots: see below, note 170.

¹³⁹ Schäfer 1980, p. 6 and note 22, pls. 39.3-39.4; Schäfer and Grossman 1975, p. 83 fig. 45, pl. 56. Schäfer admits that too little material was found to conclude the whole roof was tiled.

¹⁴⁰ Schäfer and Grossman 1975, pp. 58-59, 83 (nos. 192, 193) and figs. 44-45, pl. 56.

¹⁴¹ Building VI: Kilian 1979, p. 402. Winter also describes drawings of tiles from Tiryns shown to her by Klaus Kilian, but it is unclear whether she refers to any of the tiles from Buildings II, III, or VI: Winter 1993, p. 10 and note 6.

¹⁴² Iakovides 1990, pp. 152-154 and fig. 8; Küpper 1996, pp. 105, 135 (pans Z 16-Z 18, cover Z 23), describing tiles shown him by Helene Palaiologou and Artemidos Onassoglou. The cylinder identified as a cover preserves no rim and is 14.5 cm from front to back: Küpper 1996, p. 213 fig. 122.

¹⁴³ Iakovides 1990, p. 152 note 52; the excavator showed tile fragments to Iakovides in 1985, but they are not otherwise described. Only pan tiles are reported: Iakovides 1990, p. 154 fig. 9; 2001, p. 137.

¹⁴⁴ Valmin 1938, pp. 173-185. Blegen argues convincingly that the tiles reported from Dorion were more likely to have been pithos fragments, whereas Iakovides uncritically accepts that both covers and pans were found there: Blegen 1945, p. 37; Iakovides 1990. Shear doubts the evidence from Dorion as well: Shear 1968, pp. 335-336.

Both pan tiles and semi-cylindrical covers have been found at Mycenae, Midea, and Gla. Renewed excavations in the northwest area of the citadel at Mycenae recovered 11 fragments of pans and one wheelmade cover.¹⁴⁵ The majority came from layers of debris on the floor of Room II2, and two of the pan fragments were found in different rooms of the same building. Some tile fragments are reported in the southwest area of the citadel as well.¹⁴⁶ Just outside the citadel in the area of the new museum, a complex of rooms contained some pan tiles but no covers.¹⁴⁷ The handful of pans and the lone cover tile from all of Mycenae are far less than the quantity expected from a tile spill of even a single building.

Two covers and at least 16 rim fragments from pans were found in LH IIIB contexts in several rooms on the acropolis of Midea.¹⁴⁸ On Terrace 9, both of the two covers and seven of the rim fragments lay among mud bricks, ash, and other architectural debris over the floor of Room II (Area M).¹⁴⁹ Six other rim fragments were collected nearby from debris in Room VIII. More pan tiles had fallen on the floor and against the south wall of the long, narrow Room IV on Terrace 10, but the fragments are not individually described.¹⁵⁰ Only one rim fragment came from the area of the megaron.¹⁵¹ Adding the several fragments of flat handmade plaques from these areas does not significantly increase the totals. Thus, similar to Mycenae, Midea has not produced tiles in sufficient quantity to counter the scarcity objection.

¹⁴⁵ Iakovides 2006, pp. 43-93, 148-155, 165-166; also Iakovides 1990, p. 152 note 49 (*Ergon* 1985, p. 49).

¹⁴⁶ Iakovides 1990, p. 152 note 49 (*Ergon* 1984, p. 61).

¹⁴⁷ Onassoglou 1995, p. 146. Pan fragments are reported from areas 1, 4-7, and 12, but none are illustrated. Also see Küpper 1996, p. 105 and note 749, who reports only four pan tiles.

¹⁴⁸ Åström et al. 1990, p. 21 and fig. 27; Küpper 1996, pp. 134-136 (pans Z 1-Z 14, Z 19-Z 20, covers Z 21-Z 22); Walberg 1998, pp. 88-94 (by Ioulia Tzonou), 94-95 (by Amy Ostenson), 237-238 (A1-A22, excluding the flat slabs A4, A11, A20, A21), pls. 104-106, 141.

¹⁴⁹ Walberg 1998, pp. 87-88, 95 (A5-A19, including the covers A17 and A18); three more rim fragments came from other deposits.

¹⁵⁰ Walberg 1998, pp. 48, 90-92.

¹⁵¹ Walberg 2007, pp. 66, 169 (A 73), pl. 196; also recording two other "Mycenaean Pan Tiles" without edges: Walberg 2007, p. 169 (A 74).

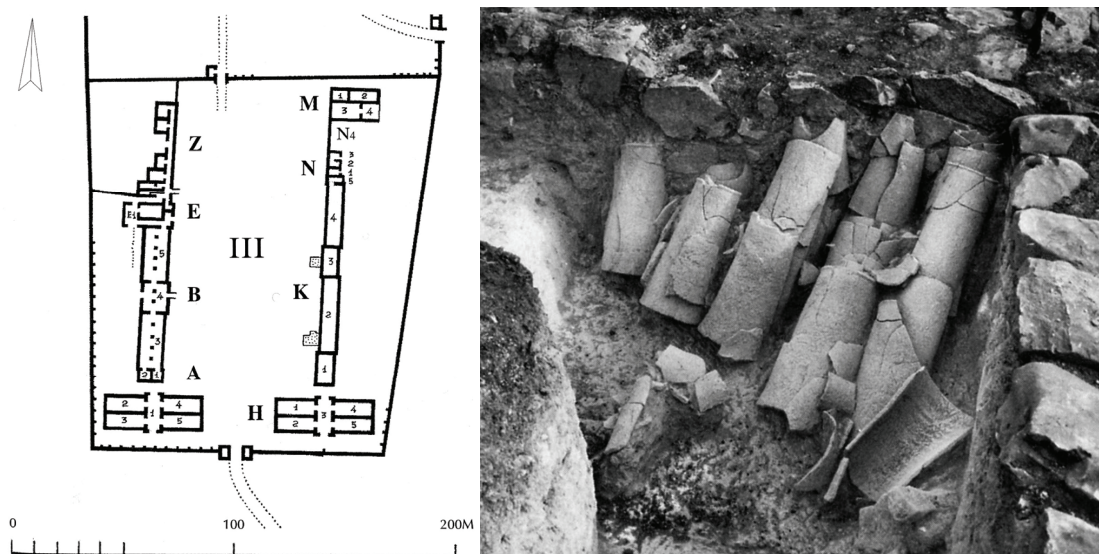


Figure 3.5 Gla: (left) plan of the South Enclosure and (right) cover tiles stacked in a courtyard to the west of the long passageway in building Z (Iakovides 2001, p. 43 plan 16; pl. 27.55)

In contrast, Iakovides and Threpsiades unearthed many tiles during their excavations at Gla.¹⁵² A total of 185 pans and 183 covers is reported, most from destruction deposits dated LH IIIB2, and there was almost no disturbance from later activity.¹⁵³ Covers and pans were found together at the Double Gate, the south entrance to the Central Enclosure, and inside rooms of Buildings E, Z, H, K, N, and M in the South Enclosure (as labeled in Figure 3.5, left).¹⁵⁴ Pan tiles alone were found at the North Gate, the West Enclosure, the Melathron, and Building B in the South Enclosure.¹⁵⁵ Relatively few cover tiles were in most of the buildings, but Threpsiades discovered a heap of largely intact covers stacked against the outside wall of Complex Z (Figure 3.5, right). As a result, Gla has produced by far the strongest evidence for Mycenaean tiled roofs.

¹⁵² Iakovides 1989; 1990; 1998; 2001.

¹⁵³ Iakovides 1998, p. 249; 2001, pp. 135; 142-145. Elsewhere, Iakovides contradicts his figures, stating “the number of preserved pan tiles is roughly four times that of cover tiles”: Iakovides 2001, p. 112.

¹⁵⁴ Iakovides 1989, pp. 246-248, 287, 303-306, 314-315; 1998, pp. 9-60 (H), 61-98 (K), 99-115 (M), 229-242; 2001, pp. 26 (south entrance), 52 (E), 55-65 (H), 70-71 (K), 71-74 (N), 77-79 (M), 111, pls. 27:55, 53:109, 69:152-153, 70:154-155, 71:156-158.

¹⁵⁵ Iakovides 1989, pp. 295, 298, 314-315; 2001, pp. 39, 111, pl. 72:159-160.

3.B.3) *Mycenaean tiles and the scarcity objection*

It is possible to formulate a test for Iakovides' hypothesis that Mycenaean tiles belonged to hybrid roofing systems. To review, the roof-tile explanation is supported by the resemblance to tiles from the historical period that certainly belonged to roofs. However, the comparison is weaker quantitatively. Later roof tiles are generally abundant, but Mycenaean tiles are generally scarce. Iakovides offers two explanations for the scarcity objection: tiles either were scavenged for reuse on other buildings or else were thrown away by inattentive excavators.¹⁵⁶ The latter argument is difficult to sustain at all sites because, as noted by Blegen, excavators have been interested in the problem of Mycenaean roofs since the nineteenth century. Thus, the validity of the hypothesis rests primarily on the explanatory power of the scavenging argument.

Gla is the best site to test Iakovides' proposal that tile scavengers were responsible for removing most Mycenaean tiles. Regardless of how attentive to tiles the excavators of other sites had been, Iakovides and Threpsiades had recovered and identified many during their excavations at Gla. There, an unexpectedly low quantity of tiles cannot be blamed on excavator error. Furthermore, because the greatest quantity of Mycenaean covers and pans has been excavated at the site, the roof-tile hypothesis must be rejected for all Mycenaean settlements if cannot survive the scarcity objection at Gla.

First, it is possible to estimate the expected number of tiles on the site if there had there been no scavenging. All the major buildings were abandoned in LH IIIB2, when there is evidence of catastrophic destruction. Large quantities of ash, mud brick, painted plaster, and tens of thousands of potsherds covered the floors of the buildings.¹⁵⁷ Iakovides describes copious evidence throughout the site that all the

¹⁵⁶ See above, note 130.

¹⁵⁷ e.g., about 46,000 sherds were counted from the buildings in the east wing of the South Enclosure: Iakovides 2001, p. 88. On the chronology: Iakovides 2001, pp. 142-145.

structures had been destroyed in a conflagration and subsequently abandoned.¹⁵⁸ There is no sign of activity for 900 years.

Post-depositional processes, such as topsoil erosion, may have removed some tiles along with soil layers. Excluding the Melathron, which in places had been stripped to bedrock by earlier excavations, areas of the South Enclosure were found undisturbed.¹⁵⁹ Several stratified deposits containing only Late Helladic material overlay the floors of many rooms, and some had been buried up to a meter deep in the remnants of the fallen mud-brick superstructure. The large quantity of potsherds indicates a significant fraction of the buildings and their contents had not been removed by erosion. Tiled roofs supported by wooden rafters would have collapsed during an intense fire, spilling the tiles on the ground directly over the contents of the rooms. Because many tiles would have fallen below the strata containing mud brick and plaster from the collapsed walls, a relatively high preservation rate should be expected. Conservatively, one fragment should have survived from at least 20% of the original tiles. That is, if more than 80% of the original count of tiles is missing from the building debris, scavengers must have been the cause.

The expected quantity of tiles at Gla can be estimated. The major buildings cover a substantial area, about 4,600 m² (above, Figure 3.5, left).¹⁶⁰ Allowing some room for overlaps, the typical Mycenaean pans restored by Iakovides would have covered an area about 0.40 m wide (upslope) by 0.50 m long (in course) and weighed about 7 kg.¹⁶¹ Again excluding the Melathron, cleared during early excavations, about

¹⁵⁸ e.g., Iakovides 1989, pp. 300, 307; 2001, pp. 41-42, 55, 81, 84.

¹⁵⁹ Iakovides 1989, pp. 277-278; 1998, pp. 225-227; 2001, pp. 6, 9-10, 29, 42. However, the depth of preservation varies across the site.

¹⁶⁰ i.e., the Melathron extends about 80 m at an average width of ca. 13 m; the two elongated halls A-B-E-Z and K-N together are 200 m long and at least 10 m wide; Building M is ca. 13 x 20 m; and Buildings A and H are ca. 15 x 45 m each.

¹⁶¹ Iakovides 1990, p. 155; 2001, p. 52. An average pan tile is assumed to be 0.460 m square (measured at its maximum length) and 0.018 m thick. Each tile would contain about 4.0 L of fired clay, whose bulk density is typically 1.75 kg/L.

18,000 pan tiles weighing 125 metric tons would have been necessary to roof the remaining buildings in the South Enclosure. There would also have been approximately as many covers. The excavated total of about 370 tile fragments from the entire citadel represents about 1% of the original count. However, with a 20% preservation rate, the expected quantity is lower—about 7,200 cover and pan tiles weighing more than 30 metric tons. Thus, the excavations recovered only about 5% of the expected number of tiles for the buildings in the South Enclosure. In other words, under Iakovides' hypothesis, scavengers must have removed at least 95% of the tiles from the site.

No matter how thoroughly they pick through the debris, scavengers have little use for broken tiles. In fact, if the buildings had burned, many tiles would have fallen and shattered along with the pots inside the buildings. The scavenging hypothesis demands that at least 95% of the tiles were intact and reused at the time Gla was abandoned, yet this is inconceivable after a fire. Nevertheless, in Iakovides' explanation, the scavengers must have ransacked the interiors of all the buildings. They must have looted the vast majority of the roof tiles, broken or unbroken, from the site, sifting through building debris to pick most rooms clean of all fragments of cover tiles. This scenario, of course, is implausible.

The only viable explanation for the relatively low quantity of tiles at Gla is that scavengers systematically dismantled the tiled roofs from the site before any buildings burned. However, no compelling evidence supports this interpretation. The scavengers may have removed small objects made from valuable materials, which are uncommon at the site, but they left behind much pottery. Despite abandoning the pottery inside the buildings, the looters must have stripped the roofs and transported at least 24 metric tons of tiles to another LH IIIC site where the tiles subsequently vanished. Moreover, to retain Iakovides' hypothesis, it must be assumed that the scavengers

Table 3.1 Findspots and quantities of tiles excavated at Gla¹⁶²
(Only plaques with rims may be identified as pans with certainty)

Findspot	Covers	Pans (all)	Pan (rims)	Citation
Building A	-	-	-	<i>Gla</i> I, pp. 167-177
“ “ H	2	24	1	<i>Gla</i> II, pp. 9-61, 131
“ “ B	-	2	2	<i>Gla</i> I, p. 182
“ “ E	1	3	3	<i>Gla</i> I, pp. 192-197
“ “ K	4	14	7	<i>Gla</i> II, pp. 69-71, 131
“ “ N	15	5	4	<i>Gla</i> II, pp. 76-92, 131
“ “ M	2	94	20	<i>Gla</i> II, pp. 105-113, 131
Complex Z	-	7	6	<i>Gla</i> I, pp. 204-206
Cover stockpile	144	23	2	<i>Gla</i> I, pp. 211-214
Melathron	-	17	17	<i>Gla</i> I, pp. 114, 148
Gates / other	15	13	5	<i>Gla</i> I, pp. 30-102, 217-29
Totals	183	202	67	

picked most of the site clean. Yet, incredibly, they ignored the stockpile of intact cover tiles leaning against the outside wall of Complex Z. The presence of this stockpile is inconsistent with an organized removal of tiles and instead suggests that the covers had no great value to the final Bronze Age occupants of the site. Therefore, scavengers cannot be blamed for an apparent scarcity of tiles at Gla, and the hypothesis that all of the roofs at the site were tiled should be rejected.

The argument for Mycenaean roof tiles cannot be salvaged for individual buildings either. Table 3.1 presents the total number of tiles from each sector of Gla according to the detailed context descriptions. The buildings A to Z, all in the Central Enclosure, are listed in order of their approximate positions from south to north (as above, Figure 3.5, left). This building-by-building analysis reveals that, contrary to Iakovides' implications, the covers and pans are not evenly distributed throughout the site. Instead, the majority are concentrated in two places at the north side of the South Enclosure: Building M, with 47% of the pan fragments, and the courtyard with the

¹⁶² *Gla* I = Iakovides 1989; *Gla* II = Iakovides 1998. The total number of pans listed in the context reports is slightly higher than the total of 185 given elsewhere by Iakovides: see above, note 153.

cover tile stockpile outside complex Z, with 79% of the cover fragments.¹⁶³ Because the cover tiles stacked outside Complex Z were stockpiled, their intended function is uncertain. Neither can the pans in Building M have belonged to a hybrid tiled roof. Such a roof should have roughly equal numbers of covers and pans, yet only two covers were excavated to match the 94 pans. Furthermore, all the tiles were found in just two rooms on the east half of the building. Similar to the cover tiles heaped outside Complex Z, the collection of pan tiles in Building M is more likely to have been a stockpile than fallen from a roof. Subtracting these examples, only 39 covers and 108 pans were found on the remainder of the site, and no more than 26 pieces came from any one building. As at Mycenae or Midea, the architectural contexts at Gla contained only small scatters of tiles insufficient to be interpreted as collapsed tiled roofs.

To conclude, the quantity of tiles from Gla falls well short of the expectation for buildings destroyed by fire. The hypothesis that Late Helladic buildings had gabled roofs protected by interlocking tiles must be rejected. Whatever their function, the tiles did not cover a significant area of any Mycenaean roof.

3.B.4) *An alternative hypothesis for the function of Late Helladic tiles*

Another explanation for the function of Mycenaean tiles is necessary. Due to the difference in manufacturing technique of the wheelmade covers and the handmade pans, the fabrics are different and, thus, may not have belonged to a single interlocking system. The fact that many more sites have pans than have covers suggests that the two could be used independently from each other.

¹⁶³ Although 23 handmade plaques of fired clay were recovered near the stockpile as well, only the two preserving rims can be positively identified as pan tiles.

Blegen argued that the Mycenaean pans were actually used as drains. For support, he cited his discovery at Zygouries of a row of four overlapping pan tiles installed as a drain on the floor of a pottery workshop.¹⁶⁴ Other drains—all shallow conduits with low rims resembling Mycenaean pan tiles—were installed at Knossos, and similar conduits are known from Mycenae, Prosymna, Tiryns, Midea, Pylos, and Phylakopi within the Mycenaean architectural milieu.¹⁶⁵ Terracotta drain tiles resemble pan tiles so closely that rim fragments often can be distinguished only by an arbitrary cutoff in height. Generally, if the side rims are less than 6 cm tall, the tile is designated a pan—if higher, a drain.¹⁶⁶ The two rim fragments from the Mycenaean Fountain on the Athenian Acropolis may well have belonged to a drain. The explanation is viable for the pan tiles from Berbati and Thebes, which were found in graves,¹⁶⁷ and too little has been published from Chalandritsa to make a determination.

However, the drain hypothesis is inadequate for some cases. Although the rims of a few *in situ* drain tiles are less than 6 cm high, the tiles are generally long and narrow—for example, 16 x 66 cm at Prosymna or 24-38 x 92 cm at Zygouries.¹⁶⁸ Intact pan tiles are less attenuated, ranging from 31 x 46 to 50 x 66 cm. No tiles of these proportions have been documented *in situ* as drains. Instead, at Mycenae, Chania, Tiryns, Midea, and Gla, the pan tiles have been found among collapsed building debris, such as fragments of mud brick and stone slabs, suggesting that they had fallen from above. According to the contexts, the pan tiles were installed on the

¹⁶⁴ Blegen 1928, p. 35 and p. 34 fig 31; 1945, p. 41. Tile fragments nearby indicate that the watercourse continued farther.

¹⁶⁵ Mycenae, Prosymna, Tiryns, Pylos, Phylakopi: Blegen 1945, pp. 40-41; Shear 1968, pp. 434-435, 445-446, 790-792 and notes 527, 790-798. Midea: Åström et al. 1990, p. 16 and fig. 20; Küpper 1996, p. 105.

¹⁶⁶ e.g., Åkerström 1945, p. 170 and fig. 10 no. 5; Küpper 1996, p. 107; Walberg 1998, p. 94.

¹⁶⁷ Keramopoulos entertains the possibility for the rim fragments from Thebes: Keramopoulos 1917, p. 76 fig. 58.

¹⁶⁸ Blegen 1928, p. 35; Shear 1968, p. 653 note 795.

roof, yet the quantities are completely inadequate for covering the rooms from which they were excavated.

The drain- and roof-tile hypotheses of Blegen and Iakovides may be combined into a simpler and more effective explanation. The basic function of all roof tiles is the same: they channel rainwater away from the building and eject the stream from the eaves. Since this function is analogous to a drain, it is no surprise when pan tiles resemble drain tiles. The contexts with Mycenaean pans indicate that small numbers of drain tiles were sometimes installed on roofs, where they must have directed water away from the building. With flat roofs, there are many situations where channeling water would be necessary. Mycenaean houses, such as those at Mycenae and Midea, often share party walls, and the multi-room complexes have an irregular perimeter that would have been difficult to roof and drain.¹⁶⁹ At Gla, the buildings such as the Melathron or complex Z are rectangular but cover an extensive area that would also have been difficult to drain with a flat roof. Residents who found rainwater pooling on the roofs of these complexes could install gutters to divert the water, and they would be likely to adapt a familiar type of terracotta drain tile to the problem. The rims of such gutter tiles would not need to be particularly high because the only purpose of a gutter is to shunt water away from a house, not to keep the whole roof dry. In order to interlock and channel water effectively, the pans must be tilted at a low slope, meaning they could be installed only in places that could accommodate such a slope. One such position is at the junction of two flat roofs of different heights. A row of pan tiles might be used to divert water into drainage channels on the ground, which are commonplace in Mycenaean settlements. For example, drains are prominent at

¹⁶⁹ See, e.g., Darcque 2005, p. 126; Shear 1968, pp. 89-92, 476-477 and notes 116, 959, both with bibliography on the related controversy over the roof of the Mycenaean megaron.

Mycenae, Tiryns, Midea, and Gla—in short, all of the sites with significant finds of Mycenaean pan tiles in an architectural context.

The cover tiles might have served different functions on the roof. The two fragments from Berbati have a wide diameter and no preserved edges, and Ione M. Shear describes them as “strikingly” similar to better-preserved chimney pots from Mycenae and Pylos.¹⁷⁰ As with the covers, Mycenaean chimney pots are wheelmade, but the known examples are complete cylinders whose diameters are significantly greater than those of the covers. The single fragments from Mycenae and Chania may also have been used as chimney pots, although their diameters appear to have been relatively narrow.

Semi-cylindrical cover tiles, however, should not be restored as chimney pots. Two fragments at Midea and about 180 covers from Gla, the majority stacked outside complex Z, are the only reliably identified examples. Most of these covers were found near pan tiles. A reasonable proposal is that these covers were normally used as water conduits. In fact, Archaic Laconian covers were occasionally reused upside-down as drains.¹⁷¹ Projecting from the eaves of the building, the Mycenaean covers could have been spouts keeping water away from the walls, a function to which the pan tiles are not well suited. Alternatively, the covers may have worked more like modern gutters by running along the eaves to catch water ejected from the roof and funnel it into a drainage system on the ground. Similar wheelmade gutters and pipes produced at factories in Sciacca are still found on some buildings in modern Sicily (Figure 3.6).

The origin of the Mycenaean covers is less clear. As wheelmade semi-cylinders, they closely resemble ancient ceramic water pipes. Fully cylindrical

¹⁷⁰ Shear 1968, pp. 11, 447-448, notes 24, 877. Pylos: Blegen and Rawson 1966, pp. 81, 200, pls. 271 (nos. 2-3, 7-9), 272 (nos. 6-9). The Pylos chimney pots taper, and their diameters range from 45-67 cm.

¹⁷¹ e.g., the cover tiles of the Heraion at Olympia were installed as drains in the Roman period: Heiden 1995, p. 188.



Figure 3.6 Wheelmade terracotta gutters on the museum at Gaggera (Selinus)

wheelmade drainpipes are common in Near Eastern architecture from the fourth through the second millennia B.C.,¹⁷² but this technology does not appear to have been adopted by the Mycenaeans. Only the wheelmade chimney pots might have been antecedent to the Mycenaean semi-cylindrical covers, but these have a very different function on a roof. Regardless, there are no prototypes for either covers or pans used as roofs tiles in earlier Mycenaean architecture.

To review, scholars have offered two explanations for Mycenaean tiles. Both should be rejected. The drain hypothesis offered by Blegen does not explain the findspots of many pans or the function of the semi-cylindrical covers. Iakovides' reassertion of the "hybrid" tile roofing system for Mycenaeans is unnecessarily complicated and unwarranted by the evidence. Cover tiles are extremely rare outside of Gla, and, in general, the roof-tile hypothesis can be sustained only by a model with impossibly voracious tile scavengers.

¹⁷² Hemker 1993, pp. 104-107.

The alternative hypothesis offered here explains the findspots, the scarcity, and the form of Mycenaean tiles. When a building collapses, gutter tiles installed on the roof would fall among the other architectural debris. Gutter tiles to channel water from flat roofs are useful but unnecessary, perhaps only improvised after the pooling of rainwater became a problem. These drains may have occupied a relatively small percentage of the roof area, consistent with the low numbers of fragments from all Mycenaean sites. It also is unsurprising that only a minority of Mycenaean settlements concentrated in the Argolid actually adopted this tactic, because there are many alternate solutions for draining flat roofs that might have been developed elsewhere. The pans and covers could have been derived from existing models—the pans from drain tiles installed on the ground, and the covers from wheelmade chimney pots.

3.B.5) *Tiles in the Early Iron Age*

Even if the Mycenaean tiles could be explained as elements of a hybrid roofing system, there is no compelling evidence that such a tradition could have survived the Early Iron Age. The architecture from the period appears too irregular and insubstantial to have supported the weight of a tiled roof. Moreover, the decades of excavations at hundreds of sites occupied from the eleventh through the eighth centuries B.C. have failed to identify clearly any fragments of tiles. Alexander Mazarakis Ainian's recent survey of the architecture from this period mentions only a few dubious reports of tiles in contexts dating before the seventh century.¹⁷³ A small clay fragment from Building B at Koukounaries may not be correctly identified as a tile.¹⁷⁴ Keramopoulos associated tiles scattered around the area of the Ismenion with a

¹⁷³ Mazarakis Ainian 1997, pp. 258, 277-278 and pp. 258 notes 2084-2087, 272 note 8, 278 note 46. Billot and Badie cite these passages as demonstrating that a tile-making tradition survived from the Bronze Age through the seventh century BC, yet Mazarakis Ainian is dismissive of the evidence: Badie and Billot 2003, p. 287.

¹⁷⁴ Skilardi 1982, p. 247.

Geometric temple.¹⁷⁵ However, his assessment as well as the existence of the temple itself is doubted.¹⁷⁶ The only report that describes a context with collapsed tiles comes from Building J at Kato Syme in southeastern Crete. Geometric to Classical strata were excavated in the area, and the report neither illustrates the tiles nor presents strong evidence for a pre-Archaic date.¹⁷⁷ Besides the examples listed by Mazarakis Ainian,¹⁷⁸ a single pan tile was excavated at Lefkandi from a context with Late Geometric pottery.¹⁷⁹ The tile is clearly a developed Corinthian type of the sixth century B.C. and should date the context rather than vice-versa.¹⁸⁰

Early building models generally do not depict tiled roofs. The eighth- and seventh-century models from the sites nearest Corinth, Perachora and the Argive Heraion, have steep slopes consistent with thatched roofs.¹⁸¹ Other early models have flat roofs inappropriate for tiles.¹⁸² A temple model from Ithaka dated ca. 700 B.C. has been cited as the only possible example of a tiled roof that predates the Old Temple.¹⁸³ As restored, the hut has an apsidal back end and a steep roof, suggestive of thatch, but the fragments from the roof are also painted in a checkerboard pattern resembling tiles. Robinson compared the checkerboard to the roof of the Old Temple, which

¹⁷⁵ Keramopoulos 1917, pp. 60, 75-77. The same report identifies roof tiles in nearby prehistoric tombs: above, note 135.

¹⁷⁶ e.g., Drerup 1969, p. 69; Mazarakis Ainian 1997, pp. 242, 312.

¹⁷⁷ Lebesse 1974, p. 223. Tiles appear elsewhere in Crete only in the sixth century BC. Aegean Island system antefixes and simas have been found at Gortyn, Knossos, and Palaikastro: Winter 1993, pp. 255-258, 261, 268.

¹⁷⁸ I have not discussed evidence for tiles reported from Vathy Limenari because I am unable to locate the publication cited by Mazarakis Ainian (1997, p. 258 note 2085). However, the small houses from the remote settlement on Donousa are unlikely to have preserved the only tradition of tile making in the Geometric period: Mazarakis Ainian 1997, pp. 194-195.

¹⁷⁹ Popham, Sackett, and Themelis 1979, pp. 85, 89, 90, 93 and pls. 69.k, 69.l, 72.2.

¹⁸⁰ Winter 1993, p. 12 note 1.

¹⁸¹ Dinsmoor 1950, p. 43; Schattner 1990, pp. 22-26 (cat. 1), 33-39 (cats. 6-9); Williams 1978, p. 346. Several models from Samos dated before the sixth century BC have steep roofs: Schattner 1990, pp. 46 (cat. 14), 49-50 (cat. 18), 74-78 (cats. 36-37), 80-81 (cat. 39)

¹⁸² Schattner 1990, pp. 27 (cat. 3), 44 (cat. 13), 47 (cat. 15), 53-54 (cat. 21), 57-59 (cat. 23), 65 (cat. 27), 70-71 (cat. 32).

¹⁸³ Robertson 1948, pp. 101-102, pl. 45a-g; Schattner 1990, pp. 28-31 (cat. 4), fig. 4, pl. 2.5. Also see Drerup 1969, pp. 119-120; Roebuck 1990, p. 49 note 5.

included both unpainted and black-painted tiles.¹⁸⁴ However, a recent reexamination of the model has found that the checkered fragments from the roof differ from the base by fabric and paint and, consequently, should be restored separately.¹⁸⁵ Because the roof fragments had been dated by their association with the base of the model, they no longer may be considered as evidence for an early tiled roof.¹⁸⁶ The first building models that clearly render roof tiles are the two hipped roofs from the Athenian Acropolis dated early in the sixth century B.C.¹⁸⁷

In conclusion, there is no compelling evidence for a prehistoric predecessor to the Protocorinthian tile system. The first roofs with interlocking covers and pans appear to have been developed after the Geometric period. Even if tiled roofs had been produced in Mycenaean settlements, the evidence does not support any continuity into the Early Iron Age.¹⁸⁸ Thus, as the earliest archaeologically dated building with a tiled roof, the Old Temple at Corinth may have originated the Mediterranean tradition of terracotta roof tiles. The relationships of the Protocorinthian roofing system to the other early Archaic tile systems that developed in Greece, Etruria, and Anatolia will be discussed in the final chapter.

3.C) Types of Protocorinthian tiles

The Protocorinthian roofing system¹⁸⁹ superficially resembles Laconian tiles in

¹⁸⁴ Robinson 1984, pp. 58-59.

¹⁸⁵ Morgan 2001, p. 196.

¹⁸⁶ Moreover, the checkerboard may simply be a pattern rather than a rendition of tiles: Cook 1970, p. 17 note 1; Schattner 1990, p. 189; Ö. Wikander 1992, p. 155; Williams 1978, p. 346 and note 8.

¹⁸⁷ The so-called fountain house from the Olive Tree pediment and a model of an Argive roof: Schattner 1990, pp. 26 (cat. 2), 94-96 (cat. 51), pls. 2.1, 2.2, 29.1; Winter 1993, pp. 17-18, 155-157 and figs. 16-17, pls. 60-62.

¹⁸⁸ As argued by Mazarakis Ainian 1997, p. 272 note 8 and pp. 277-278; Skoog 1998, p. 25; Ö. Wikander 1988, p. 205; Winter 1993, p. 13 note 1. Mycenaean tiles resemble the separate pans and covers of the “hybrid” tile systems developed in Italy and Anatolia, not the Protocorinthian combination tiles with gently curved covers and pans: Ö. Wikander 1988, p. 205; Winter 1993, p. 11.

¹⁸⁹ The descriptions that follow are based primarily on my observations of the 121 inventoried tiles from the Old Temple roof in the Corinth museum. Individual fragments are described in the catalogue. These

that the tiles have convexly curved covers and concave pans. Compared to the Laconian system, however, Protocorinthian covers and pans have only a modest curvature—meaning the highest point at the midpoint of the cover rises a small distance relative to its length, and the pan lowers slightly over its full length (Figure 3.8). The cover and pan profiles are unchanged for all tiles of the Protocorinthian system except for the modified covers at the front of the eaves tile. The regular, eaves, and hip tiles are all approximately 65 cm square. Each complete combination tile would have weighed between 30 and 40 kg.

3.C.1) *Orientation*

All tiles are described as having front, back, top, bottom, left, and right faces, as seen from the exterior of the completed building (below, Figure 3.9). A longitudinal dimension is measured from left to right, whereas a transverse dimension is from front to back. The thickness of the tile—that is, the shortest distance between the top and bottom faces at a given point—varies throughout due to differences in the top and bottom profiles.

Although Protocorinthian tiles have separately articulated covers and pans, each tile has been formed in combination, that is, with a cover and pan attached together (Figure 3.7). When viewed from the front, the cover tile may be either on the left (“left-handed”) or on the right (“right-handed”) of the pan. Because one type is the mirror image of the other, features common to both right- and left-handed tiles will be oriented relative to the “attached” and “free” edges of a tile’s cover and pan.

Tiles would have been laid in “horizontal rows”—that is, in courses of tiles—each constructed in succession from eaves to ridge. The consequent alignment of

represent only a small percentage of the total recovered by the excavations of Weinberg, Roebuck, and Robinson. Also see Robinson 1984; Winter 1993, pp. 15-16.

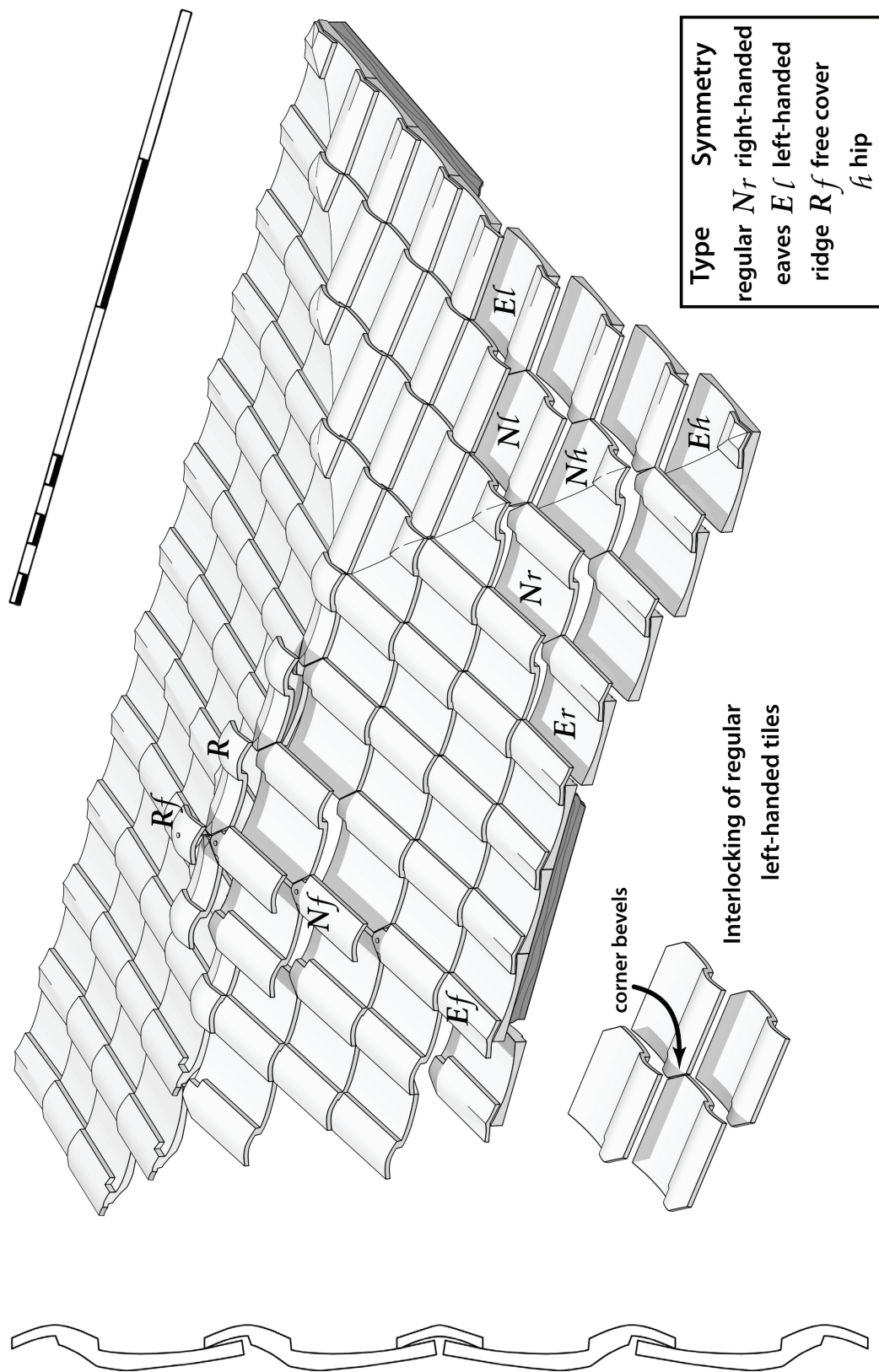


Figure 3.8 Profiles of Protocorinthian

Type	Symmetry
regular N_r	right-handed
eaves E_l	left-handed
ridge R_f	free cover
h	hip

Figure 3.7 The Protocorinthian tile system

individual tiles from one horizontal row to the next, running up the slope of the roof from eaves to ridge, is the “vertical row” (above, Figure 3.7). In order to create a waterproof seal, the tiles were overlapped by approximately 10 cm. Each tile has a transverse overlap, the portion of its upper surface that is overlapped by the tile above, and a lateral overlap, the portion of its upper surface at the free end of the pan that is overlapped by the next tile in its horizontal row.

3.C.2) Features common to all types of Protocorinthian tiles

Due to the complexity of interlocking combination tiles, various sets of bevels, notches, and rabbets (“secondary cuttings”) are required in order to accommodate the installation of neighboring tiles (Figure 3.9). The back end of the cover has been notched along its attached edge to fit the front edge of the tile above. Each tile has been beveled at the back free corner of the cover (“cover bevel”) and at the front free corner of the pan (“pan bevel”). Both bevels were cut approximately on a 45° angle to abut the diagonally adjacent tile on the roof grid (Figure 3.9). The pan rabbet has been cut back about 10 cm from the front edge of the pan in order to fit over the back end of the tile below. The cover rabbet has been cut back about 12.5 cm from the free edge of the cover to fit over the free edge of the previous tile in the horizontal row.

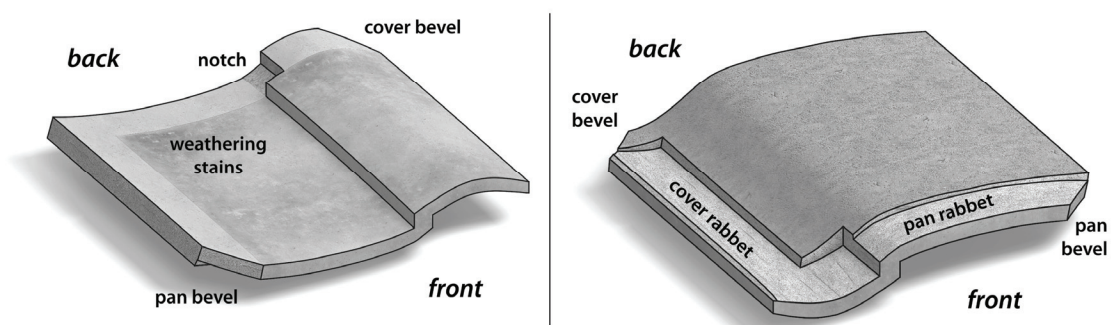


Figure 3.9 The regular combination tile, top (left) and bottom (right)

The top surfaces, the front face, and the lateral cover faces of every Protocorinthian tile are finished with a fine layer of untempered slip. Only the faces visible from the exterior of the building have been finished, whereas the back face, the lateral face of the pan, and the undersides have been left rough. The slip fired to the same pale yellow brown as the body clay, but, for the roof of the Old Temple at Corinth, a second layer of black paint has been added to certain tiles. There must have been a pattern of dark stripes on the roof at regular intervals (as above, Figure 1.1).¹⁹⁰ The underside of the tile is rough except for the cover and pan rabbets.

On many tiles, incised setting lines have been cut into the top surfaces. The lines indicate how far the two adjacent tiles were intended to overlap. The depth of the bevels and the cover notch reflect the maximum possible overlap. As is to be expected, the notches and bevels have often been overcut, allowing a slightly greater overlap than shown by the setting lines. Moreover, patches of discoloration caused by weathering (“weathering lines”) often reveal where the adjacent tiles actually had been placed on the roof. At times, the overlap indicated by the notch and weathering marks does not coincide with the overlap indicated by the incised lines.

3.C.3) *Regular combination tiles*

The regular combination tiles are the most numerous because they cover the majority of each slope of the roof (above, Figure 3.9). The standard profile of the cover and pan is continuous from front to back except for the secondary cuttings. Each

¹⁹⁰ As reconstructed by Rhodes (pers. comm. 2000). Robinson suggested a checkerboard based on the building model from Aetos: Robinson 84, pp. 58-59. Checkered patterns are restored for the polychrome archaic roof near Didyma: Schneider 1990, pp. 216-218; 1991, pp. 202-203; 1996, pp. 41-42. At the Old Temple, there are 23 black-slipped compared to 98 yellow-slipped tiles in the corpus. My calculations suggest that perhaps one-fifth of the regular and eaves tiles is painted black. Preliminary reports claim only one-seventh of the tiles was black: Robinson 1984, p. 59 and note 15. Robinson arrives at this low fraction by dividing the number of right-handed black tiles (24) by the number of right-handed tile yellow tiles (139). However, he ignores the significantly lower count of left-handed tiles (104), which artificially inflates the yellow tile count relative to the black.



**Figure 3.10 Cover rabbet, Delphi; bottom view from the free edge of the cover
(Delphi Museum inv. 21637; AR 1, Le Roy 1967;
3 cm scale card grid at bottom right)**

tile has a cover bevel and a pan bevel, and the cover is notched. The cover and pan rabbets intersect at the attached front corner of the cover.

The regular combination tiles are similar in shape and dimension at Corinth, Isthmia, Delphi, and Perachora. At Corinth, however, some regular tiles have been painted black over the buff slip finish. At Delphi, the faces of the cover are unusually thick because a raised lip remains on the underside along the front and free edges of the cover rabbet (Figure 3.10). The Isthmia tiles have been described as slightly larger than those from Corinth,¹⁹¹ but my own measurements of the tiles at both sites indicate no significant differences.¹⁹²

3.C.4) *Eaves combination tiles*

The eaves combination tiles resemble regular combination tiles with the exception of several key modifications necessary to their function as the external face

¹⁹¹ e.g., Rhodes 1984, pp. 70-96, 99-102; Winter 1993, p. 17. The dimensions originally published by Broneer, however, appear to be accurate: Broneer 1971, pp. 49-53. See chapter 9 for further discussion.

¹⁹² See below, p. 301.

of the roof. Eaves tiles have been identified among the tiles from the Old Temple at Corinth and the Temple of Poseidon at Isthmia.

The profile at the eaves has been modified so that, rather than having a convexly curved cover, the cover rises to a peak at its center (Figure 3.11). The motivation for creating a peaked “antefix” for a roof with otherwise curved covers is best understood by its relationship to the eaves pan. In the case of the regular tiles, the front face of the pan would have been visible only between the adjacent pair of covers of the tiles in the row below. However, at the eaves, an additional space at the front would have been exposed because there are no tiles below the eaves. In the Protocorinthian system, as in the later Corinthian system, this space was bridged by lengthening the pan to reach the midpoint of the cover, where it would abut the pan of the adjacent eaves tile (Figure 3.11; above, Figure 3.7). The front faces of the adjacent pans form a continuous plane at the eaves. The slightly concave curvature of the upper edge of the eaves pan is continued below the cover. In order to distinguish the cover and pan as separate entities, the front face of the cover has been set back approximately one centimeter from the face of the pan. When the eaves tiles are assembled, the concave upper profiles of the pans meet at a peak below the midpoint of every cover (above, Figure 3.7). The top profile of the cover is designed at a fixed distance from the upper edge of the pan. Because the upper edge of the pan is slightly concave, so too is the profile of the cover at both sides of the peak.

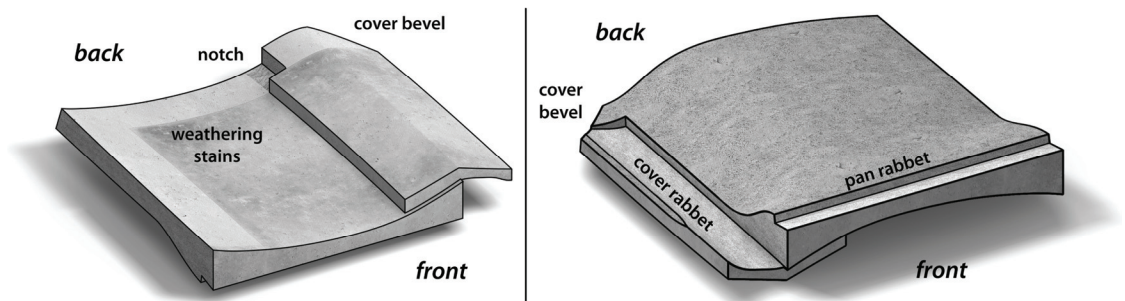


Figure 3.11 The eaves combination tile, top (*left*) and bottom (*right*)

In order to interlock with the convex cover of the regular tile above, the eaves tile must make a transition from the peaked cover at its front. At its back end, the eaves cover has the same convex curvature as a regular tile, and the upper surface makes a smooth transition over the width of the tile from the fully articulated peak at the front to the rounded back (Figure 3.11, left). For about 5-20 cm from the front edge, the ridge of the peak on the upper surface of the cover is a sharply defined cusp. By its midpoint, the cover is approximately convex. On the other hand, the concave profile of the pan is relatively uniform across the width of the eaves tile because the profile is essentially unchanged from front to back. Because there is no row of tiles in front of the eaves, the pan bevel has been omitted. A cover bevel has been cut for the row of regular tiles above.

The lower edge of the eaves pan is straight, which suggests that the front edge of the tile rested over a horizontal fascia board. The bottom has been modified to compensate. First, the underside was formed with a normal curved profile at the back, but, at 15-25 cm from the front, the profile lowers to meet the straight bottom edge of the front face, thereby increasing the volume of the pan (Figure 3.11). Second, the pan

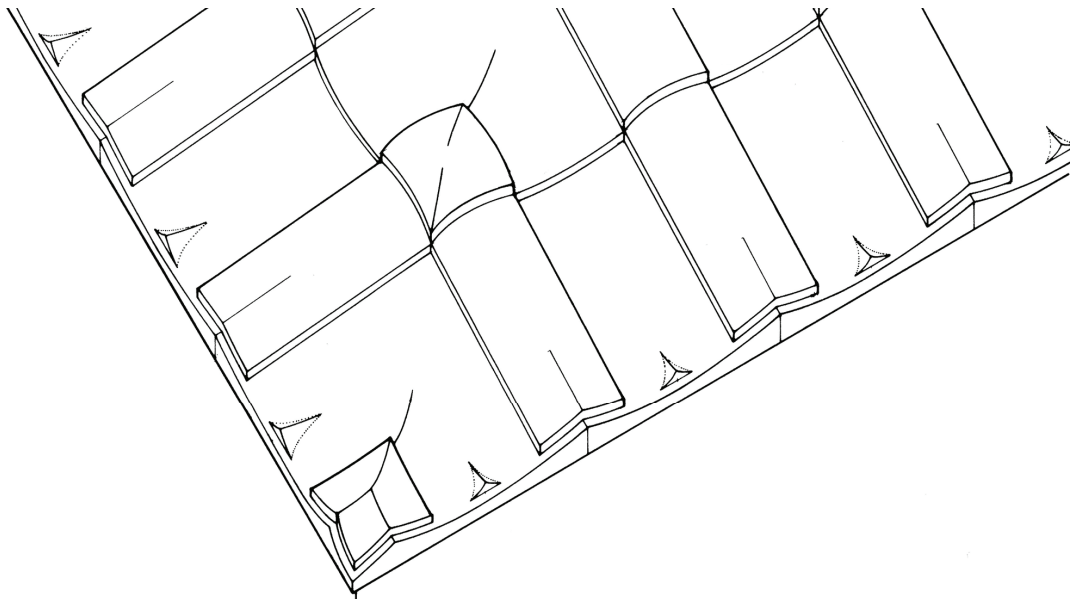


Figure 3.12 The corner of the roof at Isthmia (Hemans 1989, p. 264 fig. 3)

rabbet has the form of a narrow, flat surface about 5 cm wide that slopes up toward its back end, forming a small drip. The cover rabbet is similar to that of a regular tile.

At Corinth, some eaves tiles have been painted black over the normal pale slip finish. At Isthmia, a wedge rises from the top of the pan to create a small, triangular face about one centimeter back from the front edge (Figure 3.12).

3.C.5) *Hip combination tiles*

The hip combination tiles are the most complex of the Protocorinthian system. Their geometry is essentially that of two regular tiles meeting across the 45° diagonal line of the hip (Figure 3.13).¹⁹³ Each hip tile was the topmost tile of two vertical rows from adjacent hips of the roof. Hip tiles are identified at Corinth, Isthmia, and Delphi.

The hip line crosses the tile from the outer corner of its cover to the diagonally opposite corner of its pan. When viewed from the exterior of the building, the tile is symmetrical on the right and the left sides of the hip line. Each symmetrical half has elements corresponding to a regular tile, including a cover and pan with normal

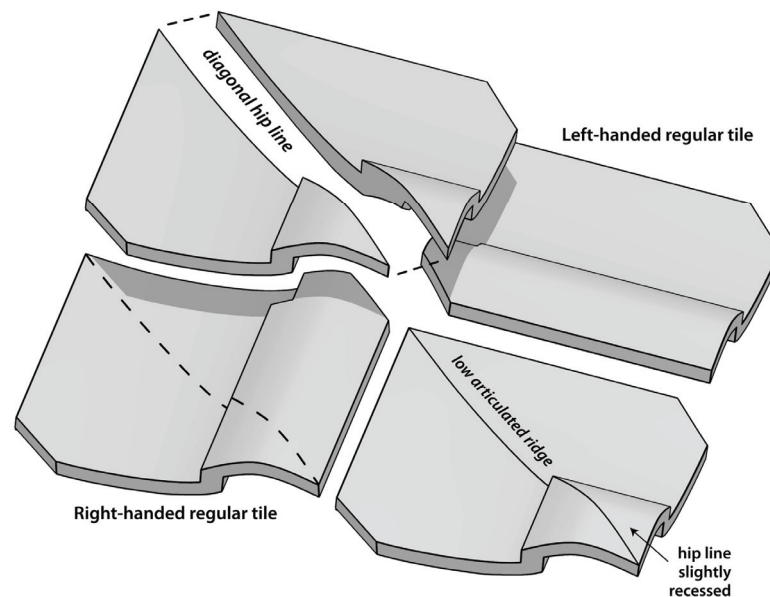


Figure 3.13 Geometry of the hip combination tiles

¹⁹³ Broneer recognized this essential characteristic of the hip tile geometry: Broneer 1971, p. 50.

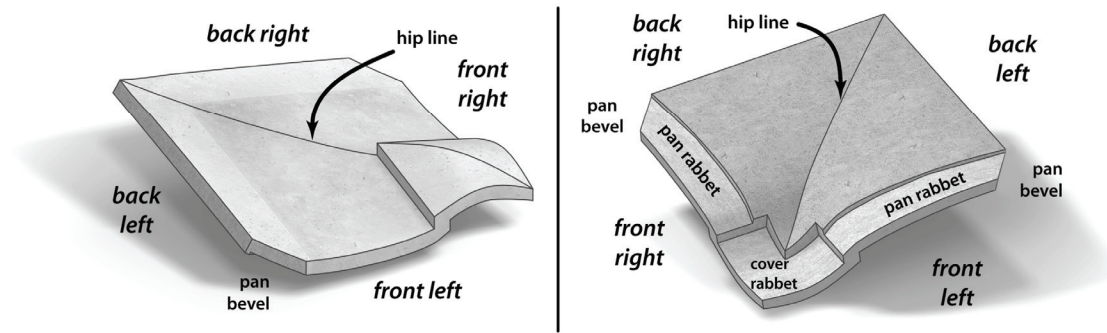


Figure 3.14 The hip combination tile, top (*left*) and bottom (*right*)

profiles, a bevel in the front free corner of the pan, a pan rabbet, and the portion of the cover rabbet in front of the hip line (Figure 3.14). The notch and bevel at the back corners of a regular cover do not appear on the hip tile because they would have been behind the hip line.

Because the right and left halves are symmetrical, there is no distinction between right-handed and left-handed hip tiles. A low ridge demarcates the hip line on the pan and the back side of the cover. At the front side of the cover is a transition from the ridge to a valley along the hip line, where the cover profile curves down (Figure 3.14). The hip tiles at Corinth, Isthmia, and Delphi are identical. No hip tiles with black paint have been identified.

A single fragment of the hip combination tile from the eaves has been identified at Isthmia (above, Figure 3.12).¹⁹⁴ Its geometry is analogous to that of the regular hip tiles, except that the halves of two eaves tiles instead of regular tiles are joined on the 45° diagonal of the hip line. As with the other eaves tiles, the cover is peaked. The left and right pan rabbets meet at the front corner, where they would fit over the intersection of the fascia boards from the two adjacent side of the building.

¹⁹⁴ Hemans 1989, pp. 262-265 and fig. 2.

3.C.6) Ridge combination tiles

The ridge combination tiles were set at the apex of the roof, where they fit over the topmost pair of regular tiles from the two hips along the flanks of the building. The ridge tile geometry is essentially that of two regular tiles set at their respective slopes and meeting at the ridge line (Figure 3.15). Ridge tiles have been identified at Corinth, Isthmia, and Delphi.

In order to maintain the normal spacings of tiles on the short hips of the roof, the width (transverse dimension) of the ridge tile is fixed by the longitudinal dimension of the covers at the center of the short hips of the roof, which is about 25 cm (above, Figure 3.7). Because of its unique symmetry, the free side of the cover is designated as the front of the ridge tile, and the free side of the pan is the back. A ridge tile has two symmetrical halves on the right and the left of the ridge line when viewed from its front. Both symmetrical halves have elements corresponding to a regular tile truncated about 12.5 cm from its front edge by the ridge line. Both sides have a pan bevel and rabbets under the cover and pan.

On the upper surfaces, the right and left halves of the pan meet at a peak over the ridge line. The sloping halves of the pan may be described as right and left gables. An articulated peak continues over the cover of some ridge tiles. Other covers instead are shaped as a smooth dome. The pan rabbets sloping down the opposite sides of the roof meet at a valley approximately on the ridge line. The cover rabbet, however, forms a continuous, curved surface under the whole area of the cover.

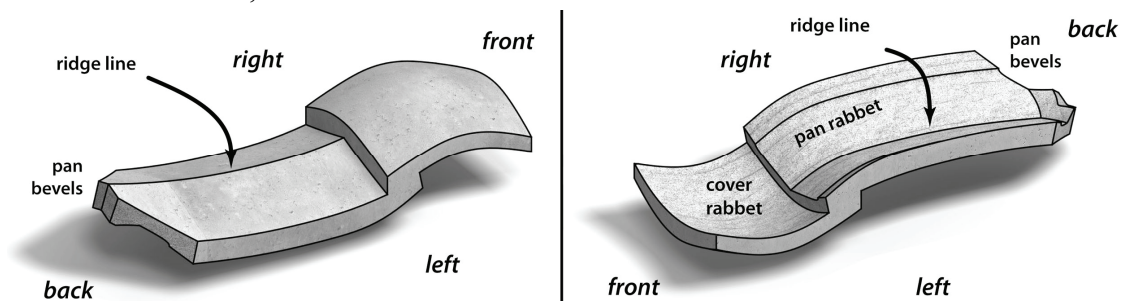


Figure 3.15 The ridge combination tile, top (*left*) and bottom (*right*)

Nails anchored several ridge tiles from Corinth and Isthmia in place.¹⁹⁵ One or two pairs of nails were driven through the pan on the opposite sides of the peak. The nail heads were countersunk, and traces of lead or iron remain in some of the holes. The ridge tiles at Corinth and Isthmia are identical.¹⁹⁶ No ridge tiles with black paint have been identified.

3.C.7) Free cover tiles

An extra cover tile is needed at the middle of every horizontal row of tiles where the free ends of the pans of opposite-handed tiles would have met (above, Figure 3.7). The free cover tile resembles a regular or eaves combination tile without its pan. Free cover tiles have been identified at Corinth and Isthmia. A single free cover is necessary on the ridge.

The free cover is oriented and described as an equivalent to the cover of a regular or eaves tile. The free cover has right and left sides when viewed from the front. The back corners of the free cover have either notches or bevels that would have accommodated the bevels of the two diagonally adjacent pans in the row above (Figure 3.7). Some free covers from Corinth have a nail driven through the rear overlap zone to anchor the tile in position. The nail hole has been countersunk, and in some cases fragments of the head and shank of an iron nail are still attached.

At Corinth, some free covers have been painted black over the buff slip finish.

3.C.8) Oblique combination tiles

Two fragments from Delphi are unique.¹⁹⁷ They resemble regular tiles with the exception that the back edge of the pan and the attached side of the cover, which

¹⁹⁵ Isthmia: Broneer 1971, pp. 52-53 (AT 22, AT 23); Hemans 1989, p. 262.

¹⁹⁶ I was unable to examine the ridge tile from Delphi; see above, note 109.

¹⁹⁷ Le Roy 1967, pp. 22-24 (AR 8, AR 10), figs. 1, 3, pls. 3, 108.

normally are perpendicular, instead are at an angle of approximately 65-70° to one another. Because only the back edge at the cover-pan joint has been preserved, the overall form of the original tiles is uncertain. The curved profile is orthogonal to the attached side of the cover, indicating that only the back edge of the pan was shifted to an oblique angle. Le Roy speculates that these tiles were adapted to a roof with oblique ridge lines.

3.D) The total number of tiles on the roof of the Old Temple at Corinth

To estimate the cost for producing the Old Temple roof (below, Chapter 8), the number of tiles must be known. Unfortunately, no traces of the foundations of the Corinth temple remain, and only a small number of tiles have been excavated. Even fewer Protocorinthian tiles have been recovered from Delphi, Perachora, and the sanctuary of Demeter and Kore. The Archaic temple of Poseidon at Isthmia is the only building with a Protocorinthian roof whose overall dimensions may be estimated. The blocks and tiles from the Corinth and Isthmia temples have a close resemblance, and the dimensions of the tiles from the two roofs are nearly identical. Given their similarities, it is plausible that the temples at Corinth and Isthmia were of similar scale.

The overall dimensions of the Isthmia building have been restored using three sets of data: traces of foundations, the spacing of the cornice blocks and rafters, and the numbers of tiles preserved in the deposit. No published study has yet considered all the evidence together, so a brief review is offered here.¹⁹⁸

Broneer proposed the first reconstruction for the Isthmia temple, a narrow building with a peristyle of 7 x 19 columns on a 14.018 x 40.024 m stylobate.¹⁹⁹ The

¹⁹⁸ Hemans is preparing a monograph on the Archaic temple: Gebhard 2001, p. 41 notes 1, 3; 2003.

¹⁹⁹ Broneer 1971, pp. 9-10, 54.

measurements, although precise, are hypothetical. Few traces can be associated with the Archaic Temple because foundation trenches for the Classical Temple were cut deep into the bedrock, obliterating any earlier features. Broneer associated bedrock cuttings and a few blocks with the north and east foundations of the Archaic stylobate, but his locations of the west and south foundations had been obscured by later trenches (see below, Figure 3.16).²⁰⁰ Besides possible trenches of a stylobate, Broneer excavated 38 circular cuttings into the bedrock irregularly spaced into five rows inside the projected area of the stylobate.²⁰¹ He suggested that the circular pits were cut for scaffolding built around the cella walls and colonnades. By interpolating between the holes and Classical foundation trenches, he fixed the dimensions of the plan to a foot unit of 0.3204 m. Broneer then fitted the columns, blocks, and tiles into a proto-Doric peripteral reconstruction matching the hypothesized dimensions from the plan.²⁰²

In a critical review of the evidence for peristyles restored to several early Archaic temples, Alfred Mallwitz challenged Broneer's restoration.²⁰³ Soon afterwards, Rhodes proposed an alternative reconstruction based on his restudy of the remains.²⁰⁴ Rhodes rejects the bedrock traces as evidence for foundations and a scaffolding system of the temple.²⁰⁵ He argues that some bedrock trenches may have been preparatory cuttings for the deeper trenches of the Classical temple rather than belonging to the Archaic foundations.²⁰⁶ The circular holes and the blocks at the north and east may have been associated with other Classical or Roman building activity. On the basis of the block cuttings, Rhodes reconstructs a building with no peristyle, which, unlike Broneer's reconstruction, more effectively explains the complex sets of

²⁰⁰ Broneer 1971, pp. 3-8.

²⁰¹ Broneer 1971, pp. 7-11.

²⁰² Broneer 1971, pp. 12-55.

²⁰³ Mallwitz 1981, pp. 621-642, especially pp. 636-637.

²⁰⁴ Rhodes 1984, pp. 43-98.

²⁰⁵ Rhodes 1984, pp. 43-59.

²⁰⁶ Rhodes 1984, p. 52.

cuttings on many of the blocks (similar to the system at Corinth; see above, Figure 3.2).²⁰⁷ Rhodes argues that the overall dimensions of the building would have been divided into even modules. The cuttings on the blocks would have supported timbers aligned with the tiles. In his restoration, two forms of cornice blocks alternate to support the tiles and reinforce major rafters (as at Corinth; above, Figure 3.2). The cornice blocks are grouped to support a bank of five eaves tiles, so Rhodes argues that the building should be restored using even multiples of five tiles over the walls plus two more tiles projecting at the eaves.²⁰⁸ In this system, the only valid options are for roof widths of 12, 22, or 32 tiles,²⁰⁹ but only the 22-tile width results in a plausible measurement. Although many alternatives are possible for the length of the building, Rhodes favors a 22-by-57-tile roof, with 4 banks of supports along the fronts and 11 banks along the flanks.²¹⁰ With tile spacing units of approximately 0.56 m, the overall dimensions would have been 12.57 x 32.17 m.²¹¹

Hemans has attempted to estimate the size of the Isthmia roof by comparing ratios of the preserved types of tiles. Broneer excavated 16,199 tile fragments altogether weighing 14,685 kg at Isthmia, an adequate sample for a meaningful statistical analysis.²¹² Because the ratios of regular, eaves, and hip tiles on the roof depend on the overall proportions of the building, the exact numbers of tiles along the width and length of the roof may be calculated for any overall width and length.²¹³ Hemans compares the relative proportions of regular, eaves, and hip tiles from the excavated material to the expected ratios for an array of widths and lengths of the

²⁰⁷ Rhodes 1984, pp. 60-74, 82-91; 1987.

²⁰⁸ Rhodes 1984, pp. 91-96.

²⁰⁹ i.e., $5 \cdot 2 + 2$, $5 \cdot 4 + 2$, or $5 \cdot 6 + 2$. Building widths of 17 or 27 tiles are untenable because an even number of tiles is necessary at the short ends of the hipped roof.

²¹⁰ Rhodes 1984, p. 95.

²¹¹ For the derivation of the spacing units, see below, p. 314f.

²¹² Hemans 1989, pp. 254-255, 260 table A.

²¹³ Hemans 1989, pp. 255-257, 265-266.

building. However, it is difficult to distinguish Protocorinthian tile types from one another, so the excavated fragments must be counted carefully. Hemans finds the minimum number of unique examples of regular and eaves tiles by separate tallies of their identifiable features, such as the notch cut in the cover or the small peak added near the front edge of the eaves pan. He tallies 563 regular tiles, 76 eaves tiles, and 15 hip tiles as the definitely unique examples of the types. A roof with 22 x 82 tiles at its eaves (11 vertical rows) best fits these ratios of tiles.²¹⁴ However, a wide range of configurations is possible from these data. The 95% confidence interval computed by Hemans includes widths from 18 to 26 tiles and a greater range of lengths, some of which include Broneer's estimate of 40 m.²¹⁵ Hemans does not discuss Rhodes' proposal for a 22-tile building width derived from the independent analysis of the cornice blocks.

The 1989 excavations at Isthmia by Gebhard and Hemans recovered further evidence of the Archaic ground plan.²¹⁶ Although the resulting publications do not discuss the earlier reconstructions proposed by Rhodes and Hemans, the excavations uncovered more trenches which may have belonged to the Archaic temple. Below the opisthodomos of the Classical temple, a shallow trench filled with debris in the Classical period may have been the robbed western foundation for the Archaic temple (Figure 3.16).²¹⁷ A series of trenches was uncovered inside the pteron of the Classical temple along the south cella wall. These rectangular trenches have an interaxial spacing of about 2.26 m, which not only appears to align with the west and east trenches associated with the Archaic phase,²¹⁸ but also is close to the spacing units of four tiles ($4 \cdot 0.56 \text{ m} = 2.24 \text{ m}$). The excavators associate the rectangular trenches with

²¹⁴ Hemans 1989, pp. 254-256.

²¹⁵ Hemans 1989, pp. 255-258, 257 table 2.

²¹⁶ Gebhard and Hemans 1992, 1998.

²¹⁷ Gebhard and Hemans 1992, pp. 27-28; 1998, pp. 9, 12-14.

²¹⁸ Gebhard and Hemans 1992, pp. 28-30.

foundations for vertical wood piers against the walls of the Archaic temple, as reconstructed by Broneer and Rhodes. Further excavation in the east area uncovered continuations of the east foundations already identified by Broneer.²¹⁹

The excavators restore the plan of the Archaic temple of Poseidon along the general outlines already proposed by Broneer. They incorporate 6 of the 38 circular pits identified as scaffolding by Broneer into the plan of the temple.²²⁰ Noting that the holes are separated by approximately twice the interaxial spacing of the rectangular piers, they suggest that the central row of holes supported the ridge beam on axis with the cella (Figure 3.16). They assign the north, west, and east trenches to stylobate foundations, and the rectangular trenches to piers on the outside of the south cella wall. The resulting peripteral building is 14.1-14.4 m wide and 39.25 m long, which is not far from Broneer's reconstruction.

The 1992 reconstruction for the Isthmia temple has not gained general acceptance, and the remains are still under analysis.²²¹ The Isthmia excavation report does not address the system of cuttings on the wall blocks identified by Rhodes as evidence for an aperipteral cella. However, if Rhodes' restoration of the architectural elements in an aperipteral building at Isthmia is accepted, the interpretation of the foundation trenches must be revised.

Some aspects of the peripteral reconstruction of the Isthmia temple from the 1992 report are dubious. The central row of posts, which are only 30-35 cm in diameter, is not appropriately aligned for supporting a ridge beam. The excavators state that the westernmost hole would have supported the west end of the ridge beam below the apex of the west hip of the roof. However, according to the published plans,

²¹⁹ Gebhard and Hemans 1992, p. 33.

²²⁰ Gebhard and Hemans 1992, pp. 30-31.

²²¹ Gebhard 2001 reiterates the conclusions of the excavation reports but adds no new evidence to support this reconstruction.

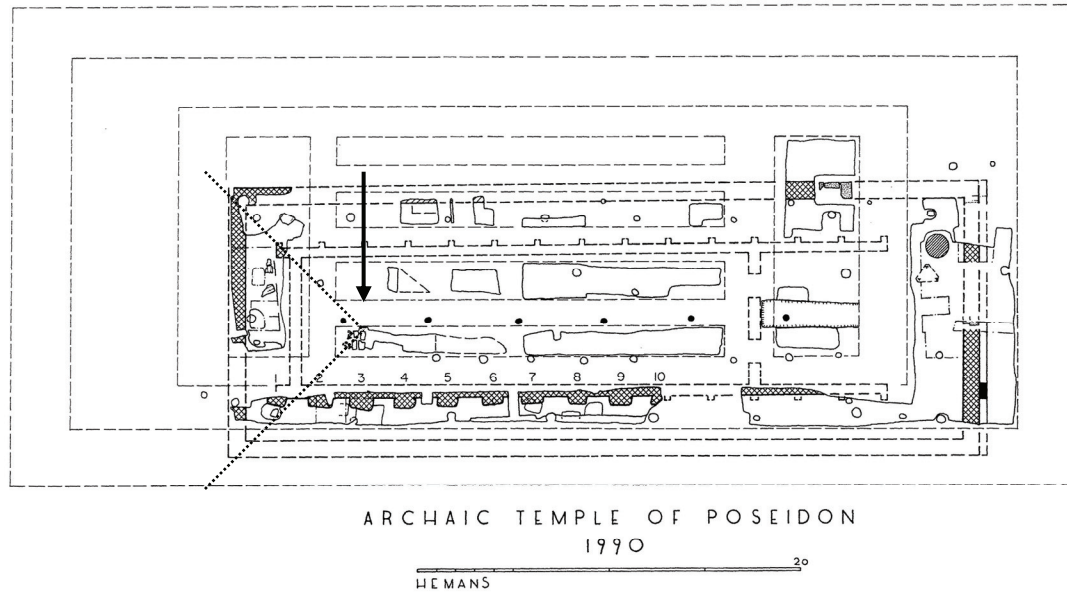


Figure 3.16 State plan of the Archaic temple of Isthmia. Dashed lines indicate foundations of the Archaic and Classical temples; crosshatched areas represent trenches believed to be robbed-out foundations of the Archaic Temple; the arrow shows the west end of the ridge line (Gebhard and Hemans 1992, p. 26 figure 6)

this circular hole is approximately one meter to the west of the end of the ridge beam, which would have been located below the apex of the west hip. This point is defined by the diagonal hip lines from the northwest and southwest corners, which would have run up at 45° angles to the walls to intersect at the axis of the building (the point has been marked in Figure 3.16). Because the ridge beam could not have extended a full meter into the area of the west hip, the westernmost circular hole is unlikely to have supported a prop for the ridge. The other circular pits in the row are interpreted as supporting posts below the length of the ridge beam, yet they are not in line with the south series of rectangular trenches, which are also associated with structural timbers by the excavators (Figure 3.16). If both the circular pits and the rectangular trenches were aligned, the case for a system of structural timbers uniting the walls, rafter, and ridge beam would have been stronger. In the end, the excavators offer no compelling explanation for why the central row of pits would have served a different function

from the 32 others on the site that they associate with scaffolding. The six central circular pits are not appropriately aligned to have served a special function supporting structural members in the finished building.

The rectangular trenches, which appear to have been cut outside the line of the south cella wall identified in the excavation report, exhibit other peculiarities. At 1.00-1.15 m across, the trenches are much larger than necessary for founding wood piers on the south cella wall, which are clearly shown by dressed panels on the wall blocks to have been only 0.32-0.34 m wide.²²² The excavators do not explain why the wall piers would have been placed in trenches three to four times larger than the piers themselves, or why the trenches they associate with wall piers are so large when the circular holes they associate with the ridge props are so narrow and deep.

A later report on the stratigraphy from the excavations indicates another oddity of the rectangular trenches. The fill inside the trenches cut a narrow strip of debris associated with the south cella wall of the Archaic temple.²²³ In the excavators' proposal, the Archaic foundations had been robbed and refilled after the destruction by fire ca. 470-450 B.C.²²⁴ With their placement of the walls, the stratigraphy indicates that the south wall was removed first. Only after their foundation trenches were filled with debris were any of the rectangular trenches cut. In other words, the trenches for the support piers restored along the south wall would have been cut only after the wall itself had been removed and backfilled. This stratigraphic sequence, if accurate, suggests that the pits did not found wooden piers attached to a south cella wall. Moreover, five other less-regular pits just to the south and filled with same type of soil

²²² Broneer 1971, pp. 15, 25-28, 35 (0.34 m average width); Gebhard and Hemans 1992, p. 30 (0.32 m width).

²²³ Gebhard and Hemans 1998, pp. 8-9.

²²⁴ See above, note 217.

as the rectangular trenches were certainly not associated with the walls.²²⁵ However, it is uncertain why any of the pits were dug from the evidence published in the reports.

If the all of the circular pits had served as bases for scaffolding or had another unrelated function, the width of the building does not need to be restored as 14.1-14.4 m. Moreover, the only substantial traces that can be associated with Archaic foundations are lines of trenches on the west, north, east, and south of the building (Figure 3.16). As argued by Mallwitz, the north and east trenches which Broneer, Gebhard, and Hemans associate with the stylobate appear more likely to have belonged to the toichobate of the cella wall,²²⁶ an interpretation which accommodates both the excavated traces and the reconstruction by Rhodes. The outer walls of the aperipteral cella proposed by Rhodes may have been founded in the three trenches on the north, west, and east. If the rectangular trenches did not found wall props, the southern edge is less clear. A cutting in the bedrock seems to extend the west foundation trench to the south of the line of these rectangular piers.²²⁷ The east foundation trench may have extended further south as well, although the excavation reports do not clearly illustrate the extension.²²⁸ If the trenches continue south into the area of the south stylobate of the Classical temple, then a building width of at least 13 m is indicated (Figure 3.16). In this case, the line of rectangular trenches would have fallen somewhere inside a wider aperipteral cella, where the trenches are unlikely to have been structural.

Regardless of the existence of a peristyle, if the west, north, and east trenches are accepted as Archaic foundations and the central holes are excluded as evidence for

²²⁵ Gebhard and Hemans 1992, p. 38; 1998, pp. 8-9.

²²⁶ Mallwitz 1981, p. 637.

²²⁷ Gebhard and Hemans 1992, pp. 27-28. A short length of bedrock cutting is said to align with the west foundation, but the area is "badly disturbed by Classical construction."

²²⁸ The trench may have terminated at a block in the foundation trenches: Gebhard and Hemans 1992, plate 12b. Hemans conducted his statistical study in 1987, before the excavations, when he accepted a widths as low as 11.5 m: Hemans 1989, p. 257.

the location of the ridge beam, only the building width is uncertain. If the south wall of an aperipteral building was founded inside the line of rectangular piers, then a building width of 11.3-12.0 m is indicated. If the Archaic foundations extended below the Classical south stylobate, the building would have been at least 13.0 m wide. The length would have been 39.0-39.5 m in any configuration. With the narrow foundations, the dimensions are equivalent to 22 x 70 or 71 tiles; with the wider foundations, the building would have required 24 or 26 tiles across the fronts.²²⁹

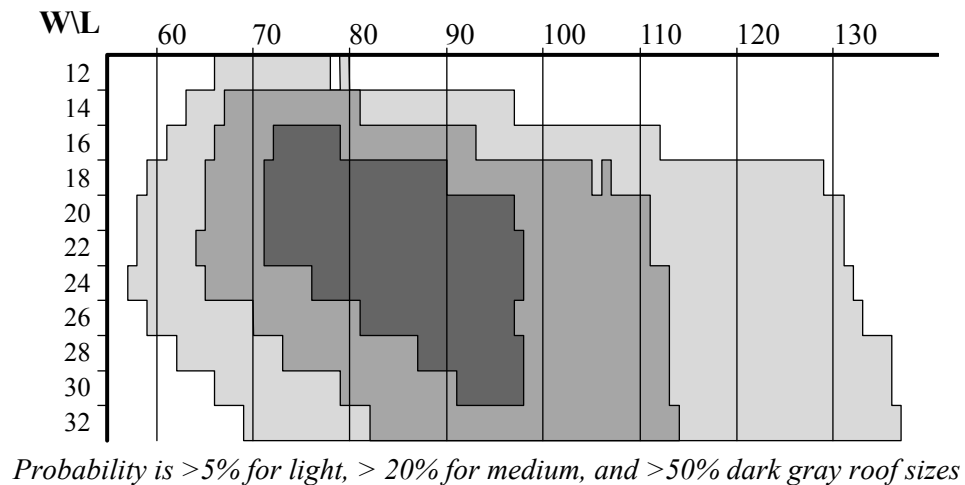
The 95% confidence intervals calculated by Hemans from the distribution of excavated tiles include the proposed dimensions of a 22- or 24-tile wide building but exclude the 26-tile width.²³⁰ However, there are reasons to doubt this calculation of the confidence interval. Hemans omits the finite population correction, which should be substantial in this case because a large percentage of the total number of roof tiles has been recovered.²³¹ The finite population correction is necessary because, for example, every hip tile excavated reduces the number of the hip tiles remaining in the ground by one and, thus, slightly reduces the probability of recovering another hip tile. When less than 5-10% of the sample is drawn, the effect of sampling without replacement on probability is minor. However, if the building is 22-26 x 70, there are only 1,360-1,632 regular and eaves tiles on the roof. The sample of 639 notch cuttings from the excavations represents 39-46% of the entire population. The probabilities for recovering the excavated ratios of tiles from the Isthmia roof should instead be modeled as a hypergeometric distribution.

²²⁹ i.e., with n tiles, an approximate tile spacing, u , of 0.56 m, and a free cover width, f , of 0.25 m, the length of one side of the building at the eaves is $nu + f$. Widths of 12.57, 13.69, and 14.81 m correspond to 22, 24, and 26 tiles, respectively. Lengths of 39.45 and 40.01 m correspond to 70 and 71 tiles, respectively. Because the eaves would have overhung the outside walls of the building by 0.25 to 0.45 m, the building at its eaves would have measured 0.5 to 0.9 m larger than its foundations.

²³⁰ Hemans 1989, p. 257, table 2.

²³¹ Cochran 1977, pp. 55-57. Hemans' z-test is an approximation calculated from an infinite population: Hemans 1989, p. 257 note 26.

Figure 3.17 Critical values of different roof sizes for producing the excavated tallies²³²



Although accurate confidence intervals for the hypergeometric distribution are difficult to calculate, a parametric simulation of the problem is a simpler alternative. Assuming an unbiased excavated sample, the problem is determining the likelihood of drawing 639 notch cuttings, 76 front edges of eaves tiles, and 16 hip tiles from an original roof of a particular width and length.²³³ Figure 3.17 presents the chances of finding the excavated ratios for roofs that are 12 to 32 tiles wide and 55 to 140 tiles long. The confidence intervals for the number of hip tiles that would have been excavated from a particular configuration of the roof are simulated for several critical values, and the results are compared to the excavated tallies.

The 95% confidence intervals are extremely broad. With a 70-tile-long building, any width from 12 to 32 tiles is possible. Assuming the roof was at least 22

²³² The chart combines two separate calculations, both simulating 5,000 random draws. The first calculation approximates the chance of drawing 16 hip tiles from a sample of 655 regular, eaves, and hip tiles. The second calculation approximates the chance of drawing 16 hip tiles from a sample of only 92 eaves and hip tiles. Both calculations produce similar results; the lower of the two probabilities is presented in the figure. The numbers of tiles on the roof has been computed by the following formulas: $R = WL - 2L - 4W + 8$; $E = 2L + 2W - 8$; $H = 2W$; where W and L are the number of tiles along the width and length of the roof, R is the regular tile count, E is the eaves tile count excluding the four corners, and H is the hip tile count including the four eaves hip tiles at the corners of the building.

²³³ Hemans tallies only 15 fragments from the upper corner of hip tiles, although 16 of such fragments are presently inventoried in the Isthmia museum.

tiles wide on the basis of the foundation traces, a 22-by-71-tile roof is the best match because the excavated tallies fall within its 50% confidence interval. Roofs from 22-26 tiles wide and 70-71 tiles long have at least a 20-50% chance of including the excavated quantities of tiles. The 22 x 57 roof proposed by Rhodes should be rejected, although the spacing of the primary and secondary support blocks at the cornice in his reconstruction could also conform to a 22 x 72 tile building.

This estimate of the dimensions of the Archaic Temple of Poseidon at Isthmia is comparable to the dimensions of the Old Temple at Corinth. As with the Isthmia system restored by Rhodes, the cornice blocks of the Old Temple may be grouped into primary and secondary supports corresponding to banks of five tiles (above, Figure 3.2). The corner blocks at Corinth differ from those restored for the Isthmia temple, and the two extra tiles projecting at the eaves are unnecessary.²³⁴ The total numbers of tiles at the eaves of the Corinth roof may have been even multiples of five. The closest dimensions to the Isthmia temple would have been 20 x 70 tiles. These dimensions, of course, are conjectural, but it is necessary to estimate the overall cost of producing the full roof in Chapter 8. A 20 x 70 Protocorinthian roof has 1,188 regular tiles, 172 eaves tiles, 36 hip tiles, 50 ridge tiles, 41 free covers, and 4 eaves hip tiles. The total weight of these 1,491 tiles is approximately 46,200 kg.

²³⁴ According to an unpublished analysis for the Greek Architecture Project at Corinth.

CHAPTER 4: AN ETHNOGRAPHIC MODEL FOR ANCIENT TILE AND BRICK PRODUCTION

To understand the likely configuration of the team of craftsmen who created the first tiled roofs, it is necessary to examine how teams of tile and brick makers operated in the recent past. Ethnographic accounts, historical treatises, economic records, and excavations of a few ancient tile-making facilities can be developed into a picture of the standard techniques and organization of tile and brick making. The methods are remarkably uniform, having changed little since Greco-Roman antiquity.

4.A) Ethnographic accounts of tile making

Hampe and Winter's ethnographic study of Italian, Greek, Turkish, and Cypriot pottery and tile workshops active between 1958 and 1962 provide the most complete record of the village industries that survived the Second World War.²³⁵ They describe a standard procedure for making cover tiles at a small family workshop in Buonabitacolo, Campania, that also threw pottery on the wheel.²³⁶ The craftsmen paddled and sieved clay that had been mined nearby and deposited at the worksite. They mixed the clay with water in a funnel-shaped pit by treading it with their bare feet (Figure 4.1). The ceramic paste for tiles was significantly wetter and more malleable than potting clay. A husband-and-wife team created the tiles together, the man forming the tiles, the woman bringing new paste and removing finished pieces. They worked at a table with a trapezoidal wood frame for the outer edges of the tiles and a wood form shaped like a tapered half cylinder for the underside of the cover tile (Figure 4.2). The cover tiles were initially formed flat. The man pressed a wad of clay

²³⁵ Hampe and Winter 1965.

²³⁶ Hampe and Winter 1965, pp. 26-29.



Figure 4.1 Buonabitacolo: Treading tile clay in a pit (Hampe and Winter 1965, p. 27 fig. 16)

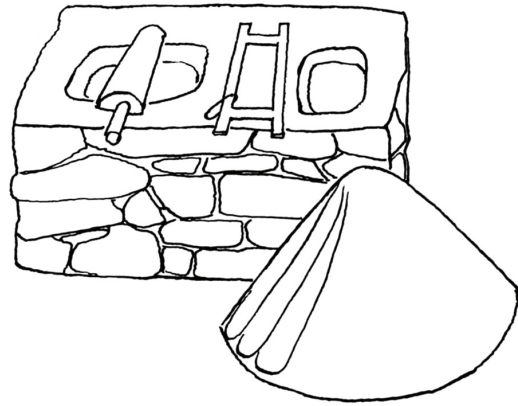


Figure 4.2 Buonabitacolo: Tile shaping tools (Hampe and Winter 1965, p. 27 fig. 17)



Figure 4.3 Bivio Segesta: Draping the sheet of clay on the semi-cylindrical cover form (Hampe and Winter 1965, pl. 42.3)



Figure 4.4 Minturno: Tiles laid out in the drying yard (Hampe and Winter 1965, pl. 15.6)

into the trapezoidal frame over a dusting of clay powder, which served as a separator layer between the sticky clay paste and the table. He smoothed the upper surface of the sheet with moistened hands; he quickly lifted the frame with the sheet of clay still adhering to its borders; and he draped it over the semi-cylindrical form (compare to Figure 4.3). The woman then pulled a string tied to the underside of the trapezoidal frame to cut the edges of the tile loose, and she returned the frame to the man to shape the next sheet. She ran her hands over the now-contoured tile and removed it from the table still on its form, setting both on the ground and pulling the form away by a

handle attached to its wider end (compare to Figure 4.4). In the mean time, the man had readied another flat sheet of clay to drape over the cylindrical form when the woman returned it to the table. Even though still very damp, the tiles deposited in the drying yard could stand unsupported because of their vaulted profiles.²³⁷ They dried rapidly at first in the direct sunlight and later were transferred to a shady, well-ventilated hall to finish curing more gradually. After reaching the oven dry state, tiles were stacked in rows resting on their short ends in a rectangular kiln for firing (compare to Figure 4.7, below).

Two tile workshops in Minturno, also in Campania, employed a very similar manufacturing process.²³⁸ Working in a shady, outdoor lumber yard, they also trod their clay in a pit and used a trapezoidal frame and a semi-cylindrical form on a table to shape their tiles. Rather than a husband and wife, however, two men assumed the same roles as in the Buonabitacolo shop. The former used sand and clay dust as a separator in the forms. Instead of just smoothing the sheet by hand after it was pressed into the trapezoidal wood frame, he used a straight-edged wooden board to flatten the tile by cutting away excess clay from above the height of the frame (Figure 4.5).

Hampe and Winter witnessed this traditional technique for creating cover tiles in many other sites in the Mediterranean. They observed tile makers active in Apulia at Corigliano and Soriano; in Sicily at Delia, Gela, Partinico, Paterno, Segesta, Sciacca, Terrasini, Villarosa, and Vittoria; in Greece at Sta Kanatadika on Euboeia and Anchangelos on Rhodes; and in Cyprus at Amochosto.²³⁹ Other ethnographers visited workshops where tiles were produced at Grottaglie in Apulia, at Mazzano Romano in

²³⁷ Hampe and Winter 1965, p. 50.

²³⁸ Hampe and Winter 1965, pp. 49-50.

²³⁹ Hampe and Winter 1965, pp. 87 (Corigliano), 95 (Soriano), 104 (Partinico), 105-106 (Terrasini), 107 (Segesta/Bivio), 107-108 (Sciacca), 116-117 (Gela), 117-118 (Vittoria), 119-120 (Villarosa), 123-124 (Paterno), 133 (Delia), 133 (Sta Kanatadika), 154-157 (Anchangelos), 163-164 (Amochosto/Famagusta).



Figure 4.5 Minturno: Flattening a sheet of clay with a board (Hampe and Winter 1965, pl. 15.4)

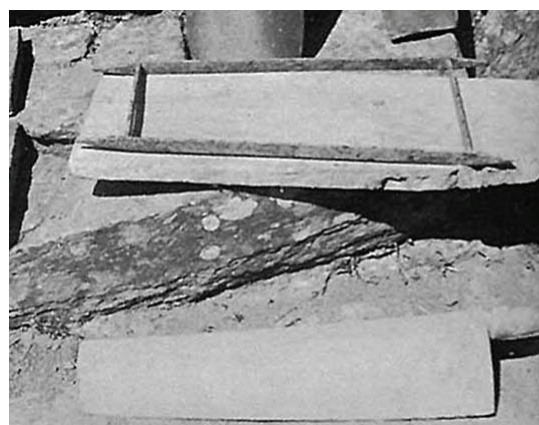


Figure 4.6 Tile-production equipment at Amochlo, Andros (Birmingham 1967, p. 34)

Lazio; in Greece at Solomos in the Corinthia, in the villages around Koroni, at modern Chalkis on Euboea, at Amolochos on Andros (Figure 4.6), at the appropriately named village of Keramida on Samos; and elsewhere at various locations on Imbros and Cyprus.²⁴⁰ All of these sites were studied after the Second World War, when the traditional ceramic industries were fighting a losing battle to competition from modern factories and cheaper alternative roofing materials. However, the old tile-making technique must have once been a staple of villages throughout Greece, Cyprus, and peninsular Italy in the centuries before the ethnographers arrived. The traditional method was transferred as far away as the Americas by Spanish colonists. At Tejar, Guatemala, the same trapezoidal wood frame and tapered cylindrical form continued to be used as recently as 1978, and similar roof tiles were produced for the Spanish Mission San Antonio in California, completed in 1781.²⁴¹

Nevertheless, a few alternatives had developed to the forming and finishing sequence of the Campanian workshops. Although the basic method for shaping the

²⁴⁰ Andros: Birmingham 1967, p. 34. Koroni: Blitzer 1990, pp. 677-678. Chalkis: Matson 1973, pp. 121-125. Cyprus: Ionas 2000, pp. 90, 133-134. Grottaglie: Cuomo di Caprio 1983, pp. 162-163 figs. 245-246, pp. 231-232. Keramida and Imbros: Psaropoulou 1984, pp. 113, 263-264. Mazzano Romano: Middleton 1997, pp. 159-161, 222 note 5. Solomos: Merker 2006, pp. 137-138; Rostoker and Gebhard 1981, pp. 213, 213 note 12, 227; Vogeikoff-Brogan 2007, p. 5.

²⁴¹ Costello 1997.

tiles was the same, some large operations which focused primarily on other types of utilitarian objects mixed their ceramic paste in a mechanical pug mill instead of hiring extra workers to tread the clay by foot. For example, the large, twenty-employee operation in Terrasini, Sicily, produced water pipes on electric wheels and occasionally made tiles, and the Mazzano Romano factory—visited by researchers from the British Museum in 1982—almost exclusively produced bricks.

Ethnographers working in the French colonies of North Africa documented other variations in the standard tile-making process. While studying the Moroccan industry at Fes between 1914 and 1916, Bel visited some workshops producing glazed cover tiles.²⁴² Although the traditional tools and forming techniques were used here as well, the process was divided among three craftsmen instead of two. One worked the clay and handed over appropriately sized lumps of clay to the second worker, who only formed the flat sheet of clay in the trapezoidal frame. The third draped the sheet on the semi-cylindrical form and deposited the contoured tile on the drying floor. After an initial firing, tiles were glazed green and refired. The whole process was transformed in Tunisia among some industrial-scale tile producers, where a cylinder was thrown on the wheel, widened on one end, and after drying a few days cut in half along its length to form two roof tiles.²⁴³ Without quantitative data, it is unclear whether the Tunisian method was in some manner superior to using the traditional forms. The inspiration for the technique might be traced to drain pipes, which were mass produced on a potters' wheel in Tunisia as well as a few centers in Sicily.²⁴⁴

²⁴² Bel 1918, pp. 177-185.

²⁴³ Djerba: Combès and Louis 1967, pp. 188-191. Nabeul: Lisse and Louis 1956, p. 147.

²⁴⁴ e.g., Nabeul: Lisse and Louis 1956, p. 150; Terrasini: above, note 239.

4.B) Brick making and kilns in ethnographic and historical accounts

Many aspects of traditional Mediterranean tile making are left unresolved in the ethnographic accounts. The ethnographers who describe the process were interested primarily in pottery, spending only a brief time—often less than a day—at any particular tile workshop. It is unclear whether the two craftsmen who formed tiles had assistants for mining and preparing clay; and the seasons of activity, the firing cycles, and the annual productivity are not discussed. The brick industry, however, represents a useful proxy for restoring these economic aspects of tile production.

Brick-making operations are common in the Mediterranean to the present day, but like workshops at Nabeul in Tunisia with nine permanent employees and enormous kilns,²⁴⁵ these industries have been sufficiently transformed by modern technology that their production techniques are unreliable for drawing analogies to antiquity. The ancient methods survive elsewhere.

Hampe and Winter noticed that bricks were produced using very similar techniques to tiles, often in the same locations. They describe brick-making frames at the shop in Buonabitacolo; and, at Minturno, they watched workers form pairs of bricks in a double frame. The craftsmen dusted dry clay powder over the frame as a separator layer, then they packed the same mixture of paste used for tiles into the forms, and they smoothed the upper surfaces of the pair of bricks by hand or with a board. The bricks were carried to a drying yard and cut from the frames. As with tile makers, two craftsmen cooperated throughout the process in large production runs: a former and a carrier.²⁴⁶ In fact, the only significant difference in the forming of bricks from tiles, besides overall proportions, is the omission of the semi-cylindrical form used to contour the tile.

²⁴⁵ Lisse and Louis 1956, pp. 148-150.

²⁴⁶ Hampe and Winter 1965, p. 49.

The system for forming bricks in pre-industrial settings is strikingly uniform, having changed little since its first appearance in the eighth millennium B.C.²⁴⁷ For example, Dobson described the traditional method still in practice at English brickworks in 1850; Matson examined large, modern workshops in Iraq where bricks were still packed into frames by hand; and mud bricks were universal in vernacular Mediterranean architecture and continue to be produced, for example, in many villages of Turkey.²⁴⁸ In Dobson's English terminology, the majority of traditional Mediterranean brick makers use a "pallet" mold coated with sand as a separator layer.²⁴⁹ The "clot" of tempered clay is dashed into the mold to fill it completely, and at the open face of the frame the clot is cut back by running it over with a "strike," usually a wooden straightedge.

4.C) Organization and productivity of tile and brick makers

Peacock developed several models for brick and tile production within the Roman economy.²⁵⁰ Besides rare examples of household production, the most common is the "small rural brickyard," where about six men worked for most of the year creating bricks, the majority distributed within 16 km of the work site.²⁵¹ The dispersed distribution of the brickyards is imposed by two major constraints: the large volume of clay required for forming bricks, and the demand for cheap bricks for building projects. Thus, in order to keep prices low, brick makers should minimize transport costs both from the clay extraction site and to their markets. A high degree of mobility among individual craftsmen was common in the historical and ethnographic

²⁴⁷ Aurenche 1993, p. 84.

²⁴⁸ England: Dobson [1850] 1971, vol. 1, pp. 27-28, 29, 70 and p. 70, fig 7. Iraq: Matson 1985. Domestic brick production: Webster 1979, pp. 285-287.

²⁴⁹ Dobson [1850] 1971, vol. 1, pp. 27-28.

²⁵⁰ Peacock 1979.

²⁵¹ Peacock 1979, pp. 6-7.

records from Northern Europe and Kenya. Rather than shipping their products from a fixed location to meet constantly shifting demand from construction projects, it was easier for brick makers to transport their equipment and build temporary kilns nearby a new short-term market.

Other models of brick production were fixed at one site. The “nucleated brickyard complex” arises around good clay deposits where inexpensive transportation to a large population also provides a stable demand.²⁵² Estate and municipal brickworks are generally small-scale operations whose principal purpose was to supply bricks for a large or steady demand anticipated by the owner, although estate brickworks would occasionally engage in commercial production.

The small rural brickyard has been described many times. Writing well before the Industrial Revolution in 1693, John Houghton described a typical brickyard in Surrey.²⁵³ Workmen produced two standard dimensions of fired bricks with pallet molds and a strike. An individual former could create 1,000 bricks a day on his own, but, teamed with a “temperer” and an apprentice, he might shape as many as 2,000 or 3,000. Houghton’s interviews with craftsmen indicate a well-structured economy with standardized production rates, prices, and equipment across the industry. A specialized team named the “stool” comprised four men and two boys.²⁵⁴ Two craftsmen prepared and transported clay to the worksite, another two formed bricks and arranged them in the drying area, and the two boys served as porters bringing clots of clay to the work table and removing the shaped bricks in their molds to the drying area. Together the team produced approximately 8,000 to 9,000 bricks a day, approaching one million bricks over a full summer, although other brick formers claimed to make as many as 12,000 to 22,000 bricks a day. Wages per thousand bricks were five pence for the

²⁵² Peacock 1979, pp. 7-8.

²⁵³ Mountford and Celoria 1968.

²⁵⁴ Mountford and Celoria 1968, pp. 23-25.

Table 4.1 Wages and costs for seventeenth-century English brick makers, 8,000 bricks²⁵⁵

Worker	Cost (1693)	Day wage/cost (1693)	Present value
Digger (not in team)	3d / 1k bricks	2s	£10.38
Sand temper	18d / 6k br.	7d to 2s	£10.38
Water delivery	18d / 6k br.	2s	£10.38
Cart, horse, shoveler	8d (per load)	unknown	-
Total Materials	-	-	£31.14
Carter	-	2s 8d	£13.84
Earth-maker	-	2s 8d	£13.84
Porter ("Up-striker")	-	1s 4d	£6.92
Molder	-	3s 4d	£17.30
Porter ("Off-bearer")	-	1s 4d	£6.92
Stacker ("Up-ganger")	-	2s 8d	£13.84
Total Wages	-	-	£72.66
Load kiln (all workers)	£3 10s / 100k br.	5s 7d (shared)	£29.06
Firing (straw fuel)	28s / 100k br.	2s 3d	£11.62
Firing (coal)	2s / 1k br.	2s	£10.38
Firing (wood)	45s / 200k br.	1s 10d	£9.34
Total Firing	-	-	£60.40
Cart delivery	2s / mi / 1k br.	16s-64s (1-4 mi)	£83.02-332.07
Sales clerk	9s / week	~1s 10d	£9.34
Total Delivery	-	-	£92.36-341.41
Total Cost (1-4 mi)	-	-	£256.56-505.61
Revenue (good bricks)	10-12s / 1k br.	£4 to £4 15s 12d	£415-498
Revenue ("Clenkers")	4-5s / 1k br.	£1 12s to £2	£166.03-207.54

²⁵⁵ Mountford and Celoria 1968, pp. 23-26. "Clenkers" are overfired bricks which are suitable only for foundations. Houghton also reports another brick molder's account for slightly different costs, but these are excluded from the table. Modern prices for 2006 have been calculated online by the English Retail Price Index, accessed Dec. 2, 2007: <http://www.measuringworth.com/ppoweruk/>.

molder, four pence for the other adult workmen, and two pence for each of the two porters. The standard equipment and expenses incurred along the production process are presented in Table 4.1 indexed to the daily wage for 8,000 bricks and modern retail prices.

In addition to the production costs, the capital investment of £2, 12 shillings, and 9 pence (equivalent to £273.70 in 2006) includes: two molds, a strike, basins, bowls, and several water scoops for molding; for preparing paste, a variety of shovels, rakes, and four wheelbarrows; and for the kiln, three coal scuttles and a ladder.²⁵⁶ The standard brick was 9" x 4.5" x 2.5" (22.9 x 11.4 x 6.3 cm), with a volume 1.66 liters. With a 5% linear shrinkage rate, the 8,000 bricks in a day would require close to 15.5 m³ of paste.

Nucleated brickyard complexes are less common, although two were documented in Morocco and Tunisia. Bel describes a well-established cluster of about fifteen brickyards outside Fes.²⁵⁷ Proprietors in town hired one or two pairs of workers for the open sites near clay beds and a reliable water source. Tasks were divided between these two specialists. One mined, transported, and trod clay in pits at the site. The other shaped the bricks. He gathered the trodden clay from the pits and set his brick frames on the ground, forming bricks directly on the drying surface, thereby eliminating the need for a porter. The team of two could produce about 1,500 bricks a day. Another crew of four staffed large kilns for firing batches of 15,000 or more bricks at once over a ten-day cycle. Although not documented in as much detail, another rural nucleation of brickyards had developed outside Tetouan, Tunisia, where unglazed tiles were also produced.²⁵⁸ Both of these cases suggest the number of brick makers in a team need not be so high. The large, fixed kilns were the most significant

²⁵⁶ Mountford and Celoria 1968, p. 24.

²⁵⁷ Bel 1918, pp. 39-57.

²⁵⁸ Joly 1906, pp. 325-329.

installations and required a large but temporary staff. The brickyards at Solomos in the Corinthia were similarly organized, with large kilns nearby a rich clay source.²⁵⁹

Falling outside Peacock's models of specialized production, several small, family operations encountered by Hampe and Winter created tiles, bricks, and pottery according to regional demand. Besides the husband-and-wife team at Buonabitacolo, the only potter interviewed at Partinico made all three products, explaining there was sufficient demand for each to keep him in business full time. The lone tile maker in Sciacca also threw pottery in the summer, making tiles and bricks over winter due to difficulties with the pots' cracking. Other potters who met smaller demands for tiles were found at Amochosto, Delia, Gela, Grottaglie, and Vittoria. Although the forming and finishing of tiles were carried out by only two workers, it is clear from Hampe and Winter's study that the full workshop often included several assistants.²⁶⁰ Family-run shops usually had three or more active workers, where a father and son performed more challenging tasks while the mother and younger children assisted by sieving and kneading clay. Larger shops added paid employees instead of family members and could manage both pottery and tile making. Mediterranean operations dedicated exclusively to brick making had teams as large as five or six men, like the English team in seventeenth-century Surrey.

Speed is clearly a priority for tile and brick specialists, because the prices of individual units had to be kept low in order to be affordable for most construction projects. The forming and finishing sequence is efficient, sacrificing quality relative to pottery production in order to save time. A large volume of paste is prepared at once by foot treading, and the more laborious hand wedging is dispensed with altogether.²⁶¹ Although some potters age freshly mined clay in the open air for several days, weeks,

²⁵⁹ Merker 2006, pp. 137-138.

²⁶⁰ Hampe and Winter 1965, p. 200.

²⁶¹ Bel 1918, p. 50; Hampe and Winter 1965, pp. 178-179.

or even months to allow its decomposition by microorganisms, so much material is required for tile production that at most only a few days' worth of ceramic paste can be efficiently stockpiled at a time.²⁶²

The usual division of labor into teams of two allows the motor operations of the forming and finishing sequence to be reduced to simple, repetitive actions. As a result, the daily productivity reported by many tile makers is remarkably uniform. A pair of workers at Minturno reported making 800 to 1,000 cover tiles a day; at Villarossa, 900 to 1,000 a day. At Gela, a single tile maker performing the whole production sequence himself still could form about 500 units a day, which is close to the production rate per worker of 400 to 500 units at Minturno and Villarossa. An exception is the husband-and-wife team at Sta Kanatadika, who claimed to produce 1600 to 1800 tiles a day using the traditional method—or 800 to 900 units per worker. They used a metal trapezoidal frame, although Hampe and Winter did not believe it conferred any advantage over the typical wood frame. Unfortunately, Bel does not report the quantity of tiles produced in a day by the unusual three-person team at Fes. However, the productivity of brick makers is relatively consistent with these figures, even without attempting to control for the size of individual bricks. Daily production per worker is approximately 700 to 1,000 bricks for Houghton's small teams, rising to about 1,500 bricks for the six-person stool.²⁶³ The small teams at Fes created about 750 bricks per worker. A team of two brick makers at Omar Hayat Khan in Pakistan produced about 500 to 600 bricks per worker each day, including gathering and mixing the clay in the morning.²⁶⁴ These figures are somewhat higher than the 500 bricks per worker estimated for Roman *bessales* by DeLaine, who draws from

²⁶² Brick-makers at Fes soaked their clay for 12 hours or overnight before molding: Bel 1918, p. 50.

²⁶³ i.e., 2000 bricks-day for 3 men = 667 bricks/man-day; 1000 bricks-day for 1 man; 9000 bricks-day for 6 workers = 1500 bricks/worker-day. The claims for higher daily production by brick formers do not mention their numbers of assistants.

²⁶⁴ Rye and Evans 1976, pp. 68-70.



Figure 4.7 Corigliano: Tiles loaded in the kiln (Hampe and Winter 1965, pl. 32.5)



Figure 4.8 Cover tiles on the roof an abandoned house in Penteskouphia village, west of Corinth

Pegoretti's nineteenth-century construction manual and ethnographic sources in Northern Europe.²⁶⁵

The firing cycle for tile is adapted for greater efficiency than pottery. Although a few tiles could be fired with loads of pottery in small shops with mixed production, larger-scale tile producers filled their kilns exclusively with tiles. This specialization confers two important advantages over mixed producers. First, the uniformly-profiled tiles could be tightly packed into the kiln space, which economizes on fuel (Figure 4.7). Second, because heavy tile pastes do not require the same care as finer wheelmade pottery, a firing of tiles could be done at lower temperatures without incurring unacceptable losses and thus required less time and fuel.²⁶⁶

4.D) Tile and brick production in antiquity

Many of these general patterns in the traditional brick- and tile-making industries would have changed little since antiquity. The methods for forming cover tiles are virtually unchanged since their beginnings. Long, narrow covers beginning production in the seventh century B.C. at Etruscan Acquarossa were produced in more

²⁶⁵ DeLaine 1997, p. 116 and note 64; 2001, pp. 261-262.

²⁶⁶ Cuomo di Caprio 1983, p. 232. For a description of brick clamp firings: Cardew 2002, pp. 280-284.

or less the same sequence as twentieth-century tiles in the Mediterranean and Spanish colonies in the Americas.²⁶⁷ The same method for producing cover tiles has been assumed for Archaic and Hellenistic Gordion and Roman Britain.²⁶⁸ Rounded covers together with flat pans formed the “hybrid” system, whose origins can be traced back as early as the seventh century B.C. in Etruria and South Italy, and which was disseminated broadly under the Roman empire.²⁶⁹ However, in recent Mediterranean vernacular architecture the entire roof is laid with just vaulted cover tiles. Right-side-up covers are alternated with upside-down covers, eliminating altogether the need for flat pans (above, Figure 4.8). As will be seen, pans were the larger and more challenging element of the hybrid roofing system, and their production is more comparable to Protocorinthian tiles. Unfortunately, although flat pans were occasionally produced until recently in Campania, Sicily, the Peloponnese, and Cyprus, no ethnographers have documented their production techniques.²⁷⁰

Although the picture developed from historical and ethnographic sources is incomplete, it may be supplemented by recent analyses of tegulae, Roman pan tiles with raised flanges at the sides (Figure 4.10). In a comprehensive technical study of Roman tegulae produced in Britain, Warry concludes that like bricks, tegulae were created in a four-sided wood frame resting on a pallet coated with sand as a separator layer (Figure 4.9).²⁷¹ Clay pressed into the frame was cut down first with a tensioned wire—a practice adopted from a modern English brick maker—and later smoothed down to the edges of the frame with a wooden strike. The frame was molded in such a

²⁶⁷ Ö. Wikander 1993, pp. 104-109.

²⁶⁸ Gordion: Glendinning 1996b, p. 34; Henrickson and Blackman 1999, pp. 311-312; Britain: Warry 2006, pp. 36-37.

²⁶⁹ Blagg 1979, p. 269; Ö. Wikander 1988, pp. 208-215; Wilson 1979, pp. 20-23.

²⁷⁰ Campania and Sicily: Hampe and Winter 1965, p. 38 (Montecorvino), 102 (Santo Stefano di Camastra), 207; Cyprus: Ionas 2000, p. 134; Peloponnese: the roof of the church in the deserted monastery of Vourkano on Mount Ithome, Messenia.

²⁷¹ Warry 2006, pp. 28-29, 33-34.

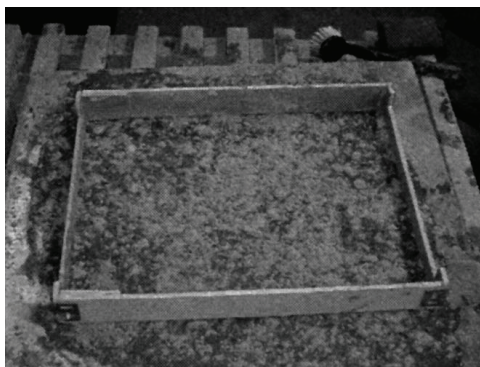


Figure 4.9 Pallet mold for producing replicas of Roman tegulae (Warry 2006, pl. 2.43)

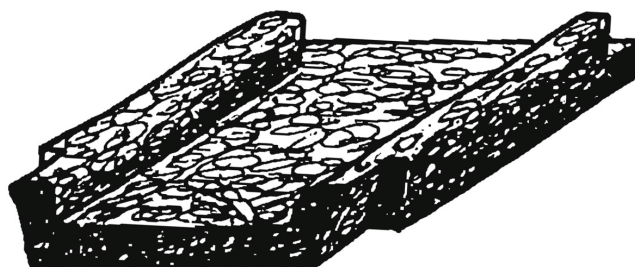


Figure 4.10 Flanged tegula (Rook 1979, p. 299 fig. 16.3)

way as to leave the raised flanges at both sides of the tile intact while striking the upper surfaces of the tile, so no extra clay needed to be applied to the flanges (Figure 4.10). Once polished, the tile was transferred to a drying area, and the frame and pallet were removed.

In this manner, an individual tile maker was expected to form 220 tegulae every day, which is known from several Roman graffiti.²⁷² The volume of clay consumed every day is at least 20% less than for modern brick makers. Warry and DeLaine assume a nineteenth-century brick maker produced bricks using about 1.3 m³ of clay in a day, whereas a Roman tile maker would have produced tiles using about 1.1 m³ in the same period. For the seventeenth-century English brick makers described by Houghton, however, an individual molder on his own produced 1,000 bricks in a day, equivalent to 2.0 m³ of paste, and the six-worker stool managed to shape 15.6 m³ of paste each day. Some of this difference in speed may be attributed to the additional production steps and care needed to create the heavier and more complicated pan tile. One tile former could produce 1,440 tegulae in a week, enough to fill a 3.0 x 2.0 x 2.0 m kiln chamber which would require about two weeks to load, fire, cool, and unload. Following the estimates for labor mining and preparing clay, transportation, acquiring

²⁷² DeLaine 1997, 114-118; 2001, pp. 261-263; Warry 2006, pp. 119-122.

fuel, and operating the kiln compiled by DeLaine for Roman brickworks, Warry calculates that in raw terms of man-power, fourteen workers with two kilns would be needed to sustain the daily production rate of 220 tiles continuously. Because the production could proceed efficiently only during only the warmest, driest months of the year around summer, Warry instead develops a labor model with a smaller team of just five workmen working year round. They spent the cool months gathering clay and fuel in preparation for an intensive season shaping and firing tiles during four months in late spring and summer.

Unfortunately, Warry does not extend this analysis to include cover tiles, nor does he compare these production rates directly with ethnographic studies. Nevertheless, it is clear that pan tiles required significantly more effort to produce than covers. Their daily production rates are approximately half those documented for cover tiles, and due to the greater bulk of pan tiles, a larger support crew was required to supply fuel for extra firings or bigger kilns. Of course, some of the additional labor cost to produce flat pans is offset by the greater area protected by each pan unit. Even if the individual covers were less expensive, roofing an area with cover tiles might cost the same as roofing it with pan tiles, because fewer pans are required. Warry demonstrates that Roman tile makers were sensitive to efficiency. Pan tiles became lighter and lighter over the course of several generations, steadily decreasing the weight and cost of roofing a fixed area.²⁷³

A tantalizing view of tile production in Archaic Etruria comes from the remains of a workshop at Poggio Civitate, the Southeast Building.²⁷⁴ An early set of architectural terracottas indicates the 51 x 6.6 meter hall had a tiled roof (Figure 4.11). Besides the collapsed tiles from the roof, others had been laid out on the packed

²⁷³ Warry 2006, p. 106.

²⁷⁴ Nielsen 1987, 1989, 1991, 1998; Nielsen and Tuck 2001; Winter 1999. Recently, the Southeast Building has been renamed “OC2/Workshop” but will be referred to below as just a “workshop”.

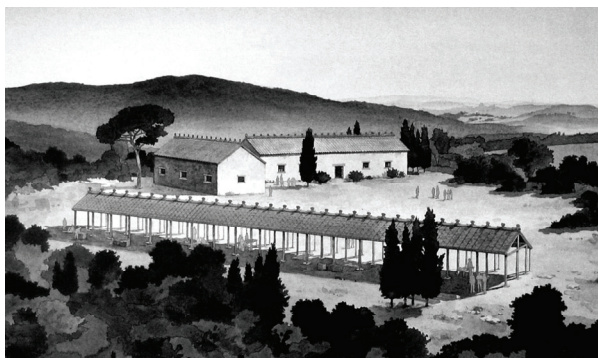


Figure 4.11 Reconstruction of the seventh-century Poggio Civitate, its workshop in the foreground (Tuck 2006, fig. 13.2)

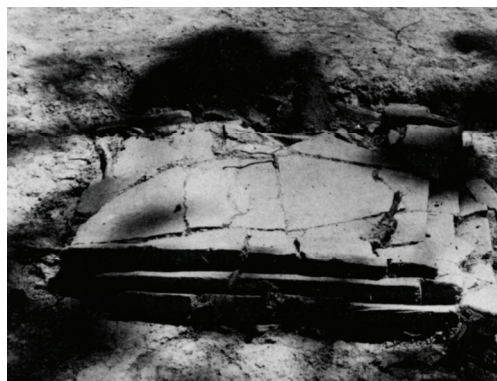


Figure 4.12 Stacked pan tiles *in situ* (Nielsen 1987, p. 94 fig. 9)



Figure 4.13 State plan of the workshop, 1984 (Nielsen 1987, fig. 4)

plaster floor at the time of the building's destruction around 600 B.C.²⁷⁵ Although heated by the burning of the building, these tiles clearly had not yet been fired. Instead, the 67 cover tiles had been laid out neatly in rows, several pan tiles were stacked upon each other (Figure 4.12), and unfired revetment plaques were present as well.²⁷⁶ A mold for a female-headed antefix confirmed production of architectural terracottas on the site. No kilns or direct evidence for pottery manufacture were recovered, but part of the Southeast Building was devoted to weaving and the manufacturing of small, decorative inlays in ivory, bone, and antler. Bronze-working

²⁷⁵ Berkin 2003, pp. 25-26. Its construction is dated between the middle and third quarter of the seventh century B.C.: Nielsen 1987, pp. 116-119; Nielsen and Tuck 2001, p. 45.

²⁷⁶ Nielsen 1987, pp. 91-92; 1998, p. 102.

tools and miscast pieces were nearby.²⁷⁷ The building had no solid walls, supported instead by three rows of colonnades (Figure 4.13). Such a well-ventilated hall was ideal for drying tiles protected from direct exposure to sun and rain. The finds clearly indicate the Southeast Building was a workshop which simultaneously produced architectural terracottas, textiles, bone inlays, and bronze.

No other studies of ancient tiles have been able to provide precise information about the organization of tile production. Little has been written about the size and organization of a Greek team, although Billot speculates that two or three tile workers might have worked within amphora production shops, citing excavations of ancient pottery workshops where tiles also were found.²⁷⁸ Ancient cover tiles are often assumed to have been produced in the same manner as the simple Italian covers described by Hampe and Winter due to their superficial similarities. However, there is no direct evidence to support or contradict this assumption, because no attempt has been made at a rigorous technical comparison with the surface markings on ancient tiles.²⁷⁹

4.E) Summary: a model for ancient tile production

In review, several generalities about traditional tile production systems which may be extended to antiquity emerge from this review of ethnographic data. A team extracts a large volume of clay exceeding one m³ each day. Workers prepare the paste rapidly by treading it with water in a shallow pit. Tiles and bricks are produced with very similar methods, using an open-topped, four-sided frame on a sanded surface. The molder polishes the upper face of the tile by hand, but often larger bricks or pan

²⁷⁷ Nielsen 1998, pp. 102-103; Nielsen and Tuck 2001, p. 37.

²⁷⁸ Billot 2000, pp. 223-225. For a review of the workshops, see the discussion below of the technology and skills of fine-ware specialists in Archaic Corinth.

²⁷⁹ See above, note 268. Also see Peacock 1979, p. 5; Winter 1993, pp. 304-306.

tiles are smoothed down to the edges of the frame using a wooden strike, sometimes after the clay has first been cut back with a tensioned wire. Although usually formed at a shaded table, tiles are then laid on the ground in direct sunlight for rapid drying. After a number of hours, they are removed to a shady but well-ventilated drying area, usually a shed. Within several days or weeks, they are fired. Workshops are located out of doors. Due to the dependency on long, sunny days to dry and fire tiles efficiently, the production season runs only from late spring through early fall.

Tiles are seldom made by one craftsman alone. The former is assisted by at least one or two porters. A minimum crew of two or three workers must reserve time to obtain and mix clay in the morning, also stopping work to rearrange drying tiles throughout the day. Moreover, the crew must break periodically to load and fire the kiln. It is impractical for tile workers to gather and stockpile enough clay and fuel during the winter due to the large volume of clay processed during the whole production season. Tile kilns do not significantly differ from pottery kilns, but a load exclusively of tiles can be fired more efficiently than one mixed with pottery. Consequently, the tendency is for specialized teams of five or six craftsmen to work full time throughout the production season when there is enough demand. In order to keep up with the former and his porter at the full-time rate of production, three or four additional workers are needed to gather clay and fuel, rearrange drying tiles, and manage the kiln. If demand exceeds the maximum productivity of the team of six laborers, instead of the team's growing larger, the tendency is for separate teams to arrive at the area. When demand is constant, a nucleated brickyard complex develops.

CHAPTER 5: PRELIMINARY HYPOTHESIS FOR FORMING AND FINISHING PROTOCOLINTHIAN TILES

5.A) Replication experiments at Isthmia

An experimental archaeological study of the roof tiles of the early Temple to Poseidon at Isthmia has already provided a number of important observations about the mass production of Protocorinthian tiles.²⁸⁰ Rostoker and Gebhard worked through the entire process from clay mining through firing, and the team included Greek workmen with brick-making experience. The manufacturing sequence used to make the replica tiles at Isthmia is important to answering the technical question of the tile system's origins.²⁸¹ The Isthmia team assumed that because the top of the tiles was smooth and even in comparison to the rough underside, the top must have been formed in a mold. Furthermore, the Isthmia team demonstrated that the tiles are too large to be formed in a two-part press mold, because using a separate top mold requires too much pressure to shape the extensive surface area of the upper half of the tile.²⁸² The Isthmia team concluded that Protocorinthian tiles had to be produced upside-down, with the clay for the replica tile built up on a molded bedding shaped like the upper surface of the tile. The team constructed large wooden molds framed by "flasks" to support the sides of the tile as clay was packed into the form.²⁸³ The flasks also were profiled like the underside of the tile, serving as templates that guided the shaping of the exposed bottom surface of the tile. Clay was packed into the form, and the exposed surface was pounded vigorously into position using a broad mallet, which left impressions over the whole underside.²⁸⁴ The experimenters cut the rabbeted shelves into the bottom

²⁸⁰ Rostoker and Gebhard 1981. The project is summarized in Gebhard 2001, pp. 57-58.

²⁸¹ Because the roofs at Corinth and Isthmia are virtually identical, Robinson followed the Isthmia replication method when describing the fabrication of the Corinth roof: Robinson 1984, p. 57 and note 8.

²⁸² Rostoker and Gebhard 1981, pp. 220-221.

²⁸³ Rostoker and Gebhard 1981, p. 221, and p. 220, fig. 16.

²⁸⁴ Rostoker and Gebhard 1981, pp. 221-222 and p. 221, fig. 18.

surface, which was accessible, and left the tile to dry. Because of a problem with the clay sticking to the molds, the Isthmia team had to experiment with other ways to extract the tile. Their solution was lining the mold with fabric sheets that helped raise the tile off its bedding.²⁸⁵ They fired the replicas to temperatures between 650 and 700 °C, which gave the clay a coloring similar to the original Protocorinthian tiles.²⁸⁶

Rostoker and Gebhard conclude that the Isthmia tiles could be produced using simple materials and tools.²⁸⁷ They observe that the “technical features of making tiles—even these giant tiles—present no obstacles that could not be overcome by an empirical approach and some ingenuity.”²⁸⁸ The authors do not pursue the ultimate origins of the technology, but rather they suggest that the knowledge could have arrived with traveling Corinthian craftsmen, presumably those with the experience of building the Old Temple at Corinth. Because the Protocorinthian tiles are so uniform, it should be assumed that the design at Isthmia would be more or less the same as at Corinth, but the Isthmia report does not pursue the ramifications of the experimental replications for the Old Temple roof.

5.B) Primary forming techniques at Corinth

Although the Isthmia team successfully produced several replica tiles, there are reasons to question the accuracy of their restoration. Surprisingly, they state that “no consideration was given to the tool marks at the time the tile experiment was planned and executed.”²⁸⁹ Instead, “one check that can be made on [their] forming procedure comes from the marks that were left on the surface of the ancient tiles by the original

²⁸⁵ Rostoker and Gebhard 1981, p. 222 and p. 223, fig. 23.

²⁸⁶ Rostoker and Gebhard 1981, pp. 222-223.

²⁸⁷ Rostoker and Gebhard 1981, pp. 225-226.

²⁸⁸ Rostoker and Gebhard 1981, p. 226.

²⁸⁹ Rostoker and Gebhard 1981, p. 223. A recent book about experimental archaeology at their time of publication explicitly advised against this approach: Coles 1979, pp. 38-39, 46-48, 160.

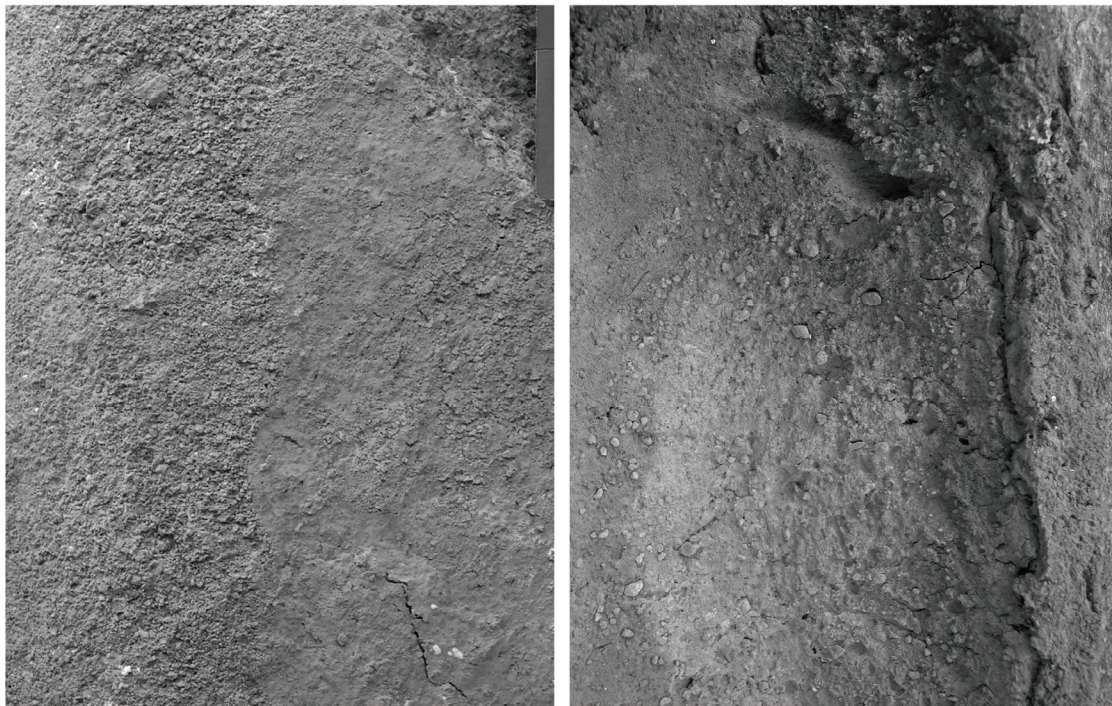


Figure 5.1 A parting agent of clay dust and gravel on the undersides of (left) a Protocorinthian tile, Corinth Inv. FT 228 (*0.03 m scale card grid at upper right edge of field*); and (right) a cover tile from the village of Delphi (*approximately equal scale*)

craftsmen.”²⁹⁰ They present several photographs of surface markings on ancient tiles, which they describe as corresponding to the markings from a knife, a spatula, and a long bar used on their replica tiles.²⁹¹ However, the authors make no serious attempt to justify the identifications despite their importance to confirming the replication procedure. There are grounds to doubt these particular tooling marks came before firing at all.²⁹²

During my examinations of the ancient tiles, I found that the Isthmia researchers had overlooked a characteristic feature of every well-preserved inventoried Protocorinthian fragment from Corinth, Isthmia, and Delphi: a fine gravel coating on

²⁹⁰ Rostoker and Gebhard 1981, p. 212.

²⁹¹ Rostoker and Gebhard 1981, p. 224 and pp. 224-225 and figs. 24-28.

²⁹² That is, the illustrated marks may have been the result of post-firing chiseling of tiles, which is described as it occurs at Corinth below, note 311.

the underside (Figure 5.1).²⁹³ It is formed of small chips of mudstone from shale deposits outcropping in the Corinthia, which splinter into a fine gravel when compressed.²⁹⁴ A layer of these particles adheres only to the lowest surfaces of the tiles, which never exhibit any patterning left by a canvas sheet or mallet marks like those on the Isthmia replicas. Instead, the evenly distributed gravel adhering to the clay surface is better interpreted as a parting agent, defined in the ceramic literature as any material used to prevent clay from sticking to a working surface such as a mold.²⁹⁵ Rather than canvas sheets, Corinthian coroplasts were using mudstone chips as a parting agent, similar to the sand, gravel, ash, or clay dust used by traditional brick and tile makers. Ethnographers have documented the use of these materials, and a separator layer has been described on the undersides of flat pan tiles from Gordion and Laconian tiles from Kalapodi.²⁹⁶ Because the parting agent adheres to the bottom of Protocorinthian tiles, the bottom must have been the molded surface, meaning the ancient tiles had actually been formed right-side-up.

The selection of mudstone as a parting agent is logical given its presence as a tempering material in the clay body of the same tiles.²⁹⁷ All Protocorinthian tiles have roughly 15-25% by volume of this tempering material, where it serves to strengthen

²⁹³ At Corinth, 77 inventoried tiles preserve a rough, gravelly undersurface, while the other 44 fragments have been retooled, eliminating the original texturing. Elizabeth Gebhard and Frederick Hemans have questioned the molding system chosen by Rostoker and Gebhard 1981, citing a comment by Le Roy: Gebhard 2003.

²⁹⁴ Mudstone is a well-known tempering material for Corinthian ceramics: Farnsworth 1970, pp. 10-11; Whitbread 1995, pp. 334-335; Whitbread 2003, p. 6 and p. 12, table 1.2. The same rough layer of tempering material appears on the undersides of archaic tiles from Acquarossa: Ö. Wikander 1993, p. 105, fig. 37.

²⁹⁵ Rye 1981, pp. 81, 146, fig. 65c. Oddly, despite using sand as a “mold release coating” for bricks made in frames for their kiln, the Isthmia team was unable to adapt the same method for their tile replicas: Rostoker and Gebhard 1981, pp. 215, 222. See also Whitbread 1995, p. 296.

²⁹⁶ Hampe and Winter 1965, pp. 28 (dry clay dust), 50 (sand or clay dust), 107 (sand), 133 (sand); Bel 1918, p. 181 (ash). Gordion: Glendinning 1996b, pp. 33-34. The Kalapodi tiles had a sandy coating on the underside for a mold: Hübner 1997, p. 141.

²⁹⁷ Whitbread identifies mudstone tempering in four Protocorinthian tiles: Whitbread 1995, p. 294 and note 4. The Isthmia tiles contain Acrocorinth shales: Rostoker and Gebhard 1981, p. 212 note 8 and pp. 213-214.

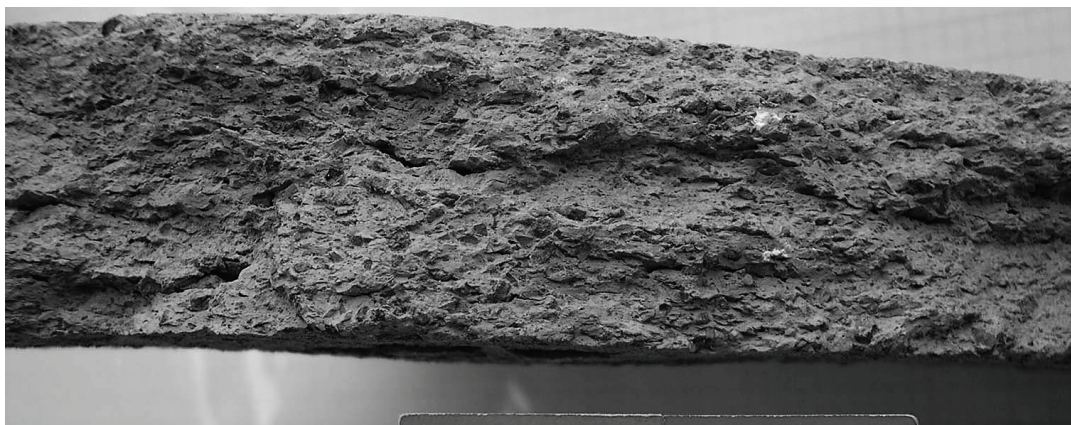


Figure 5.2 Typical fabric of a Protocorinthian tile (FP 104)

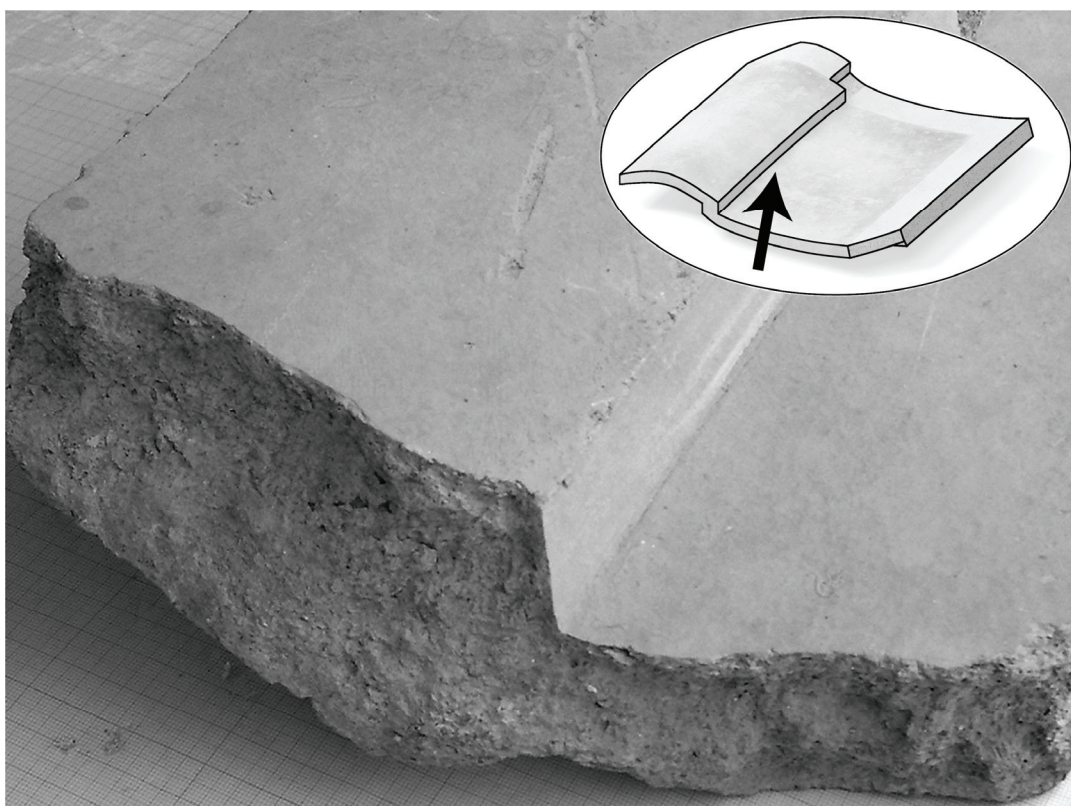


Figure 5.3 Break face across the pan-cover joint revealing the continuous fabric (FP 342)

the tile while reducing shrinkage during drying (Figure 5.2). The tile clay itself is fine-bodied. In the breaks, it usually has fired reddish brown in the core in comparison to the buff surface.²⁹⁸

²⁹⁸ The Munsell surface color reading is 10YR 7/4 (very pale brown) on over half the tiles, but for others the clay ranges within 7.5YR-2.5Y / 7-8 / 3-6. Weathering produced deeply saturated oranges up

Another important clue to the primary manufacturing technique is at the joint between the cover and pan, where it is obvious that the combination tiles were not pieced together from originally separate covers and pans. Protocorinthian tiles rarely break at this cover-pan joint, and the fabric is uniform when exposed in the break section, demonstrating that the whole tile must have been constructed as one seamless unit (Figure 5.3).²⁹⁹

It is not so obvious how the top was formed, because the entire upper surface is coated by a smooth slip which conceals the dark tempering material. In most cases, the slip removed any traces which might have indicated how the top was formed. The slip has partly broken away on a few exceptional pieces, where it reveals an undersurface with fine grooves which run from side to side, although it is uncertain whether these grooves are the result of the molding process or just a secondary feature caused by smoothing (Figure 5.4).³⁰⁰ At least it may be concluded that the top was not formed in the same way as the bottom because there is no evidence for a parting agent on the surfaces covered by the slip.

If the upper surface was not formed in a press mold, at least the consistency of the profiles when sections through several different tiles are compared suggests that the upper surface was shaped using a standardized template of some kind (Figure 5.5). Overlaid sections in the figure show that the thicknesses of individual tiles vary, but the profiles of the top and bottom are very consistent, even including the eaves tile. The highest variability is at the free end of the cover, where the underside has been cut back later to form a rabbet, and the upper profiles appear to have been distorted during this operation. The top of a tile was intended to be visible when installed on the

to 5YR 7/8 (reddish yellow) in a few spots. Where exposed in break faces, the fabric approaches 5YR 7/4 (pink) and 7.5YR 7/6 (reddish yellow), although one-sixth of the Corinth tiles are fired throughout to the surface color. See *Munsell Charts*.

²⁹⁹ Also noted by Winter 1993, p. 13, note 6.

³⁰⁰ The slip on only one other tile, FP 337, has broken away to reveal the lower surface.

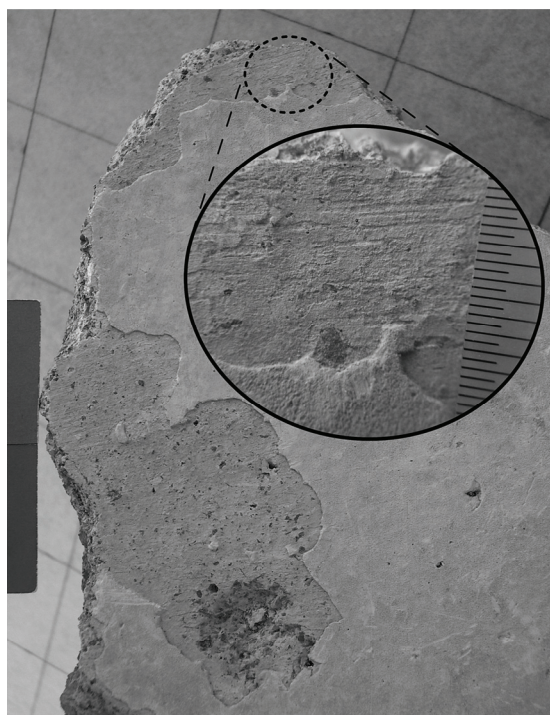


Figure 5.4 Longitudinal striations exposed beneath flaked slip (FP 326; 6 cm scale card at left; 0.5 mm gradations in inset)

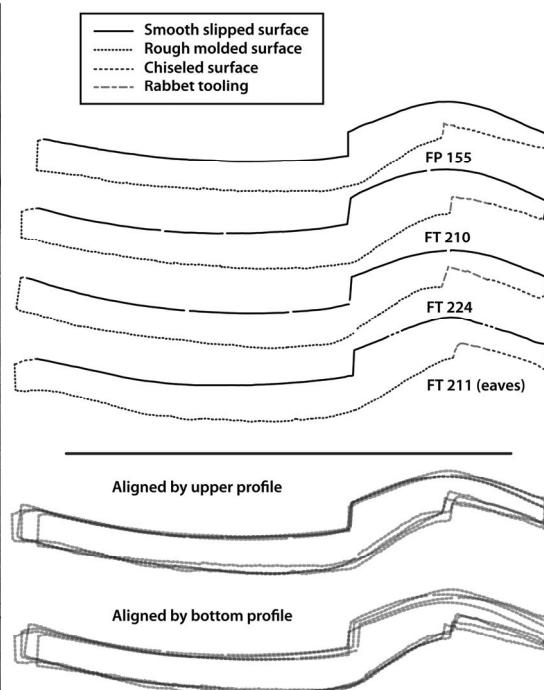


Figure 5.5 Sections at the midpoints of several complete tiles; overlays are darkest where several sections coincide

building, and it has been polished smooth in comparison with the rougher but molded underside.

A template frame is a logical alternative to a two-piece mold. The frame would have been similar to the simple rectangular wooden frames used to form bricks, Roman tegulae, or the sheet of clay later molded into a cover tile by modern tile workers (see above, Chapter 4). The curved profile of a Protocorinthian tile could have been struck by modifying the flat-topped frame for bricks or tiles. Parallel curved templates would have replaced the flat boards at the front and back sides of the mold. These templates would have guided a straight-edged scraper used to strike the upper surface of the tile down to the desired profile (below, Figure 5.7). The method is intuitive, in particular to craftsmen familiar with the frames for producing mud bricks. Furthermore, the method is similar to that employed by the Isthmia team, whose open-

topped form had templates built into its sides, although these templates only guided the shaping of the bottom of their replica tiles.³⁰¹

Another feature of the top apparently connected to the manufacturing process is “transverse bowing.” The majority of the Protocorinthian tiles bow upward from their front and back edges toward the interior (illustrated in Figure 9.10 during a later discussion). Both the top and bottom surfaces bow upward, such that the top surface is slightly convex, and the undersurface is slightly concave. The degree of bowing is slight enough that it does not appear to have been intentional. However, it is not immediately clear what manufacturing process might have been responsible for this bowing, or whether the tiles instead bowed as they dried. The problem is taken up again in Chapters 6 and 9.

The edges of Protocorinthian tiles do not preserve markings that prove or disprove the existence of such a template. The front face of the tile and the long sides of the cover were visible on the assembled roof. As a result, these faces had been smoothed with the same slip as upper surfaces, thereby removing any tooling marks. The back face and the free side of the pan, however, were not slipped, although these surfaces were generally unhelpful in analyzing the forming techniques. Some edges have an uneven face with small lumps raised around pieces of temper lodged in the body clay. More commonly, the rough surface exhibits long striations that must have been left by a cutting blade (Figure 5.6). These strokes suggest that a blade was used on the sides, probably to separate the clay from the template frame. The cuts might also be explained as secondary trimming, if for some reason the tiles were molded at a larger dimension than needed and subsequently cut down. Consequently, it is unclear

³⁰¹ Rostoker and Gebhard 1981, p. 221, fig. 17, where the “upper roof tile” in the caption refers to the underside of the finished tile. Approaching the problem from the perspective of a ceramicist, John Lambert immediately selected a board for striking out the first replica tiles destined for the Snite exhibition (see above, note 1), although at the time he had seen only drawings of the tiles.

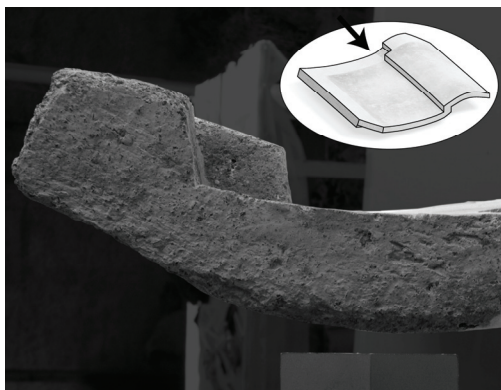


Figure 5.6 Back face with lateral hollows left by a blade stroke (FP 110; 3 cm scale card grid at bottom right)

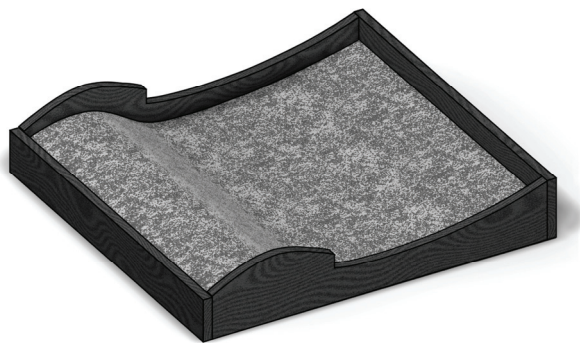


Figure 5.7 Protocorinthian regular tile base mold and frame: hypothetical system

whether the frame was exactly the size of one tile, or whether it could have been somewhat larger.³⁰² A solution is proposed below in Chapter 9.

According to the hypothesis, the primary forming of a Protocorinthian tile took place on a mold consisting of a curved bedding for the bottom, with profiled templates framing the front and the back. Before packing clay into the mold, its surface would have been covered with a layer of mudstone serving as the parting agent. The sides and upper profile of the tile would have been struck with a straightedge guided by the template frames. The templates may have been set farther apart than the full depth of a finished tile, which would have required trimming with a blade after the tile was molded. The template frames would have been a pair of wooden boards united in a stable four-sided frame fitting around the base mold (Figure 5.7). This framing system is similar to other proposals for producing Archaic and Roman roof tiles.³⁰³

³⁰² Cutting down the tiles is an unnecessarily complicated system, although it allows the depth dimension to be more carefully controlled. A large mold several tile units deep could be formed in the frame and the individual tiles cut apart later, although this would be very difficult to execute given the depth of even a single tile. The much smaller, mass-produced modern tiles are formed one at a time.

³⁰³ Ö. Wikander 1993, pp. 104-109; Rook 1979; Schneider 1991, pp. 198-199, fig. 4; 1996, p. 24; followed by Hübner 1997, p. 136, note 19 and p. 149, fig. 11; Schädler and Schneider 2004, p. 23; Warry 2006, pp. 7-36. Rook first proposed a frame system for Roman tiles, where excess clay was cut down with a wire: Rook 1979, pp. 298-301 and p. 299, fig. 16.3. Wikander suggests that grooves on the surfaces of the pan tiles from Acquarossa were the marks of a smoothing board instead of a wire: Ö. Wikander 1993, pp. 105-106, fig. 38.

5.C) Secondary forming techniques at Corinth

After the top had been smoothed, the profiled Protocorinthian tile would have been complete except for the notches and bevels needed to accommodate the ten-centimeter overlap between neighboring tiles. The surface markings of these features suggest that they were secondary formation processes, meaning that they were cut away from the volume of the tile after it had been molded.³⁰⁴ The notches frequently have drag marks and smeared wads of clay on their inner surfaces, consistent with having been cut out with a blade while the clay was still damp and sticky (Figure 5.8). The blade often cut down into the opposite face of the notch, also suggesting that the clay was soft. On the underside, the rabbeted shelves have tool casts of a different character. The rabbet surfaces have lengthwise strokes with crisp edges that sometimes preserve the width of implement used to trim the surface, a narrow straightedge (Figure 5.9). Unlike the faces of the notch, the surface within these long strokes is relatively smooth, and pieces of the temper in the fabric have been caught and dragged by the implement. The fact that the clay was stiff enough to hold fragments of temper up against the tip of the tool suggests that the clay had significantly dried by the time the rabbets were cut out. Because the rabbets are on the underside of the tile, which was resting on the mold bed during the primary forming, the craftsmen must have waited until the tile had stiffened enough to lift it from the base mold. Fingerprints on the back sides of a few tiles may have been the result of premature attempts to slide the tile free from its mold when the clay was still too soft (Figure 5.10). After the tile had hardened enough to be lifted, it would have been too stiff to accept such deep imprints.³⁰⁵ It is less clear when the corner bevels were cut.

³⁰⁴ Primary forming, secondary forming and surface modifications are adapted from terminology in Rye 1981, p. 62.

³⁰⁵ Finger impressions on the pan free edge: FP 104, FP 162, FT 210, FT 211, FT 224, FP 311, FP 340; on the back face near the cover-pan joint: FP 164, FT 210. One tile, FP 326, has parallel finger scrapes in its underside.



Figure 5.8 Cut marks on the face of the notch (FP 164; 3 cm scale card grid at bottom of field)

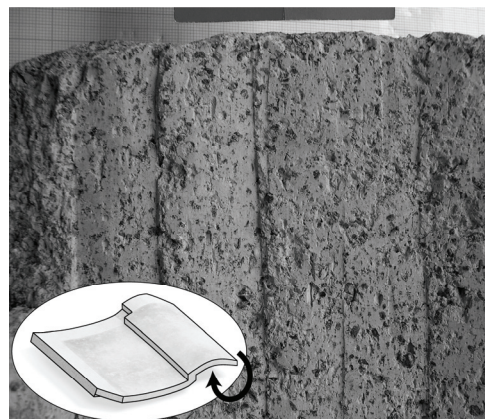


Figure 5.9 Lengthwise strokes in the cover rabbet (FC 65; 6 cm scale card width at top of field)

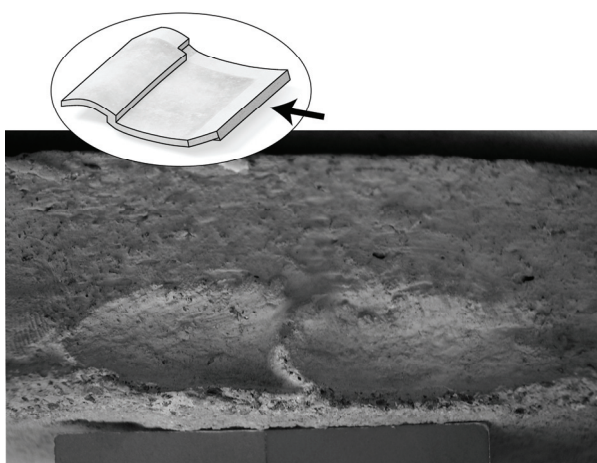


Figure 5.10 Fingerprints on the lower edge of the free end of the pan (FT 210; 3 cm scale card grid at bottom)

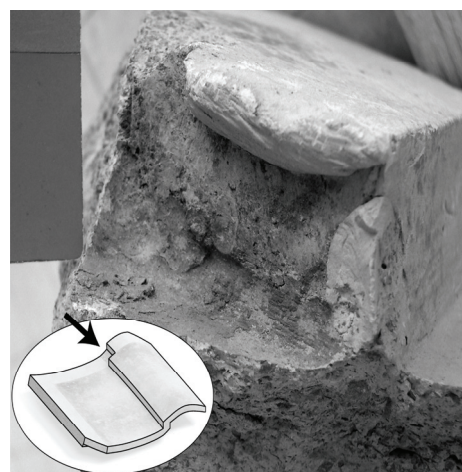


Figure 5.11 Back view of a notch with wads of excess slip wiped over the edges (FP 330; 3 cm scale card)

Their surfaces exhibit a variety of secondary tooling marks suggesting that they were cut and re-cut at different times during the finishing sequence. Finally, most tiles had incised setting guidelines on their upper surfaces. The incisions had crisp, clean edges consistent with having been cut while the clay was still leather hard.³⁰⁶

The surfaces that would be visible on the assembled roof were polished as part of the finishing process. Tiles have a fine surface layer up to 1.5 mm thick which

³⁰⁶ Rye 1981, pp. 66, 86-87, 90, and p. 67, fig. 47b. Also see Gebhard 2001, p. 59 note 99.

appears to be an applied slip. The slip is particularly distinctive in a few cases where an excess wad of the material has been wiped inside the edges of the notch (Figure 5.11). Rarely has the slip flaked away to expose the tempered fabric below (as above, Figure 5.4). Its coloring in no way differs from the fabric below it, suggesting that the slip was prepared from the same clay as the rest of the tile. However, in many cases, the smoothed surface is difficult to distinguish from the rest of the fabric, and it is possible that some of this untempered finish was self-slipped, that is, produced by smoothing the tempered body clay with moistened fingers to draw finer particles out to the surface.³⁰⁷ The slip on the pan of one tile, FC 86, has faint fingerprints which indicate that it had been polished by hand (Figure 5.12).

The dark slip wash on the black-painted tiles certainly was applied after the tile had been slipped and dried leather hard.³⁰⁸ The paint is usually a matte dark brown and often has cracked. Frequently, the paint has red splotches or is entirely reddish brown because of an uneven application or perhaps an imperfectly controlled reduction phase during firing.³⁰⁹ Only the visible faces of the tile were actually painted black, and the paint was applied only as far as the incised setting guidelines. The paint did not need to reach as far as the back and side edges of the tile, which would be covered by the overlaps the tile above and the adjacent tile after installation. Some black tiles had

³⁰⁷ Rye 1981, pp. 89-90; some Archaic tiles from near Didyma were polished in this fashion: Schneider 1996, p. 56. Most Protocorinthian tiles have a distinctive, clean coating that is more consistent with an applied slip. A similar slip has been identified on later architectural terracottas at Corinth: Whitbread 1995, p. 296; Bookidis 2000, p. 388. The tiles of a seventh-century roof from Ephesos were slipped: Schädler and Schneider 2004, pp. 23-24, 61-66. I thank Elizabeth Gebhard and Frederick Hemans for sharing with me their belief that the Protocorinthian tiles at Isthmia are not slipped (pers. comm. 2006).

³⁰⁸ Robinson 1984, pp. 57-58. Here the term "paint" is preferred so long as it remains uncertain whether the black coating is a vitrified glaze: Rye 1981, p. 54; Jones 1986, pp. 760-761; Hamer and Hamer 2004, pp. 163-167, 333-334.

³⁰⁹ In light of recent analyses of the black gloss on other ceramics, it seems more likely the black paint was produced by the reduction of iron oxides. Manganese is another possible colorant which has been detected in recent preliminary tests of sixth-century paint on terracotta sculpture at Corinth: Winter 2002, p. 49. However, manganese has not been detected in other roughly contemporary Greek or Lydian ceramics: Jones 1986: pp. 762-763, 812; Schneider 1991, p. 202; 1996, p. 56; Maniatis, Aloupi, and Stalios 1993; Hostetter 1994, pp. 48-49; Bookidis 2000, p. 392 and note 54; Henrickson, Vandiver, and Blackman 2002; Papadopoulos 2003, pp. 210-212.

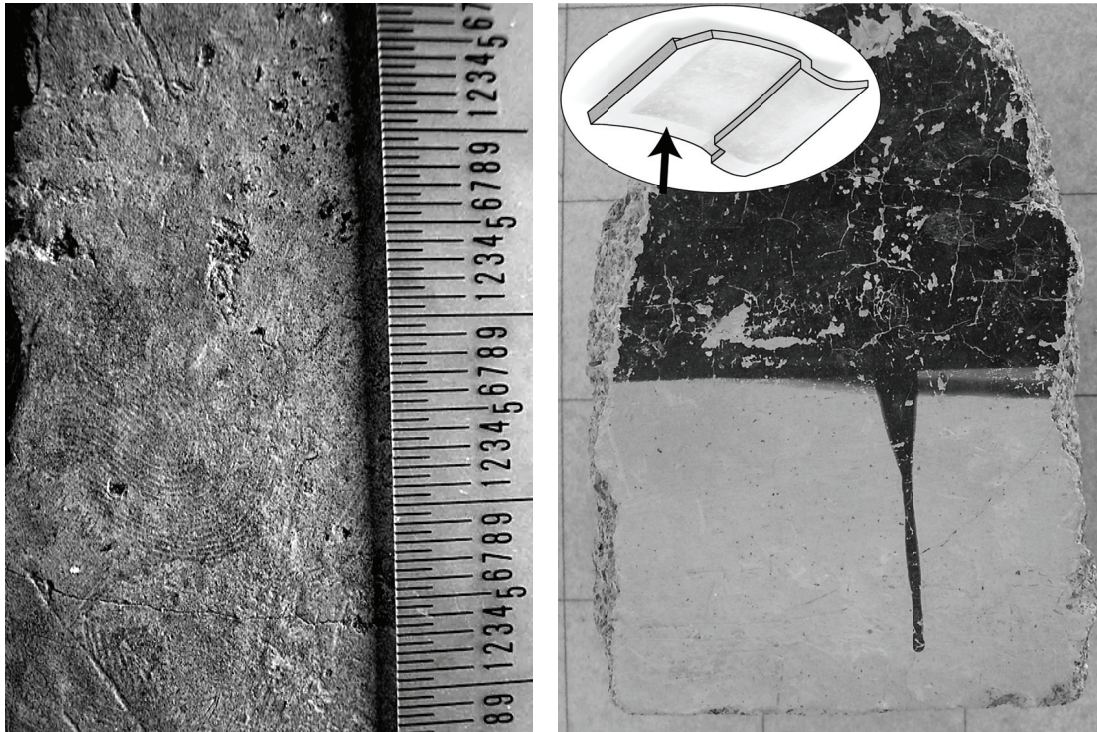


Figure 5.12 Fingerprint in the slip of the Figure 5.13 Paint dribbled over the back pan (FC 86; 0.5 mm scale gradations) edge (FP 317; 5 cm grid)

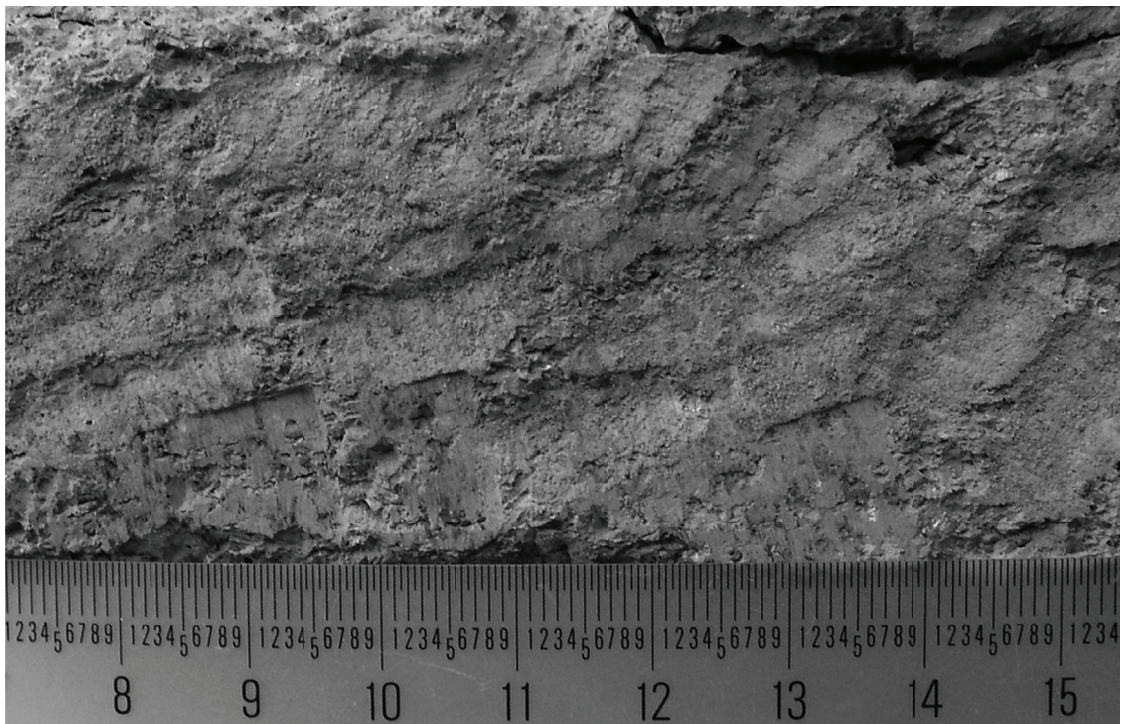


Figure 5.14 Chisel marks (scalloped) above scraper casts (temper streaks); original molded surface at the top edge of the field (cover rabbet, FP 163; 0.5 mm gradations)

dribbles of the dark wash running toward the back edge, showing that the tile had been flipped up to stand on its back end while being painted (Figure 5.13). Clearly, these tiles were painted black very late in the manufacturing process, after the tile was strong enough to be upended.

A surprising feature of Protocorinthian tiles is that usually they are chiseled on their joint surfaces (Figure 5.14). The chiseling left distinctive tool casts of a narrow blade in places where the fabric otherwise appears rough and broken. In most cases, the chiseling removed the pale buff surface of the tile to expose the reddened fabric of the core. Because this color differentiation develops during firing, the tiles could only have been chiseled after firing.³¹⁰ Apparently, the tiles were adjusted to fit one another on the roof.³¹¹ Furthermore, traces of what may be a lime mortar adhere to the surfaces of a few fragments, where the mortar would have sealed the joints between tiles or else have shored up pieces that were seated too low.³¹² Another post-firing feature of Protocorinthian tiles is the dark, irregular staining of the surface that coincides with the incised setting guidelines and unquestionably was acquired from exposure to weathering on the assembled roof.

³¹⁰ For the color differentiations of the fired fabric, see above, note 298.

³¹¹ I found chiseling fired replica tiles and discarded ancient Corinthian tiles from the excavations to be easy as long as the fragment was more than 2 cm thick and supported firmly. Post-firing tooling of Archaic tiles has been noted before, but the distinction of post-firing chiseling from other trimming marks has not been clearly explained: Broneer 1971, p. 53, nos. AT 25, AT 26; Cooper 1989, p. 39; Gebhard 2001, p. 58 note 93; Hoffelner 1999, p. 42, pl. 39.2; Hübner 1997, p. 136 and p. 150, fig. 15; Le Roy 1967, p. 205; Robinson 1984, p. 58; Ö. Wikander 1993, pp. 125-126; Schneider 1991, pp. 199, 200, 204, 205, figs. 12, 13.

³¹² A distinctive pale mortar containing a fine aggregate adheres to the joint faces and undersides of many tiles, but it remains uncertain whether this conglomerate is a manmade mortar or a natural burial accretion. I thank Ruth Siddall for examining tiles FC 29, FC 110, FP 158, FP 309, FP 311, FP 312, FP 333, FP 339, and FT 210 under a hand lens and providing me with this information. Robinson reported that tiles FP 312, FP 338, FP 342, and FP 345 had unfired wads of clay adhering to their undersides, and he cited parallels at Isthmia: Robinson 1984, p. 62, note 20; Broneer 1971, p. 52, AT 14. However, I have been able to find only fired clay wads adhering to the bottoms of two of those four tiles, FP 338 and FP 345. These two tiles had probably picked up the clay unintentionally while being manipulated in the workshop or placed in the kiln. FP 312 and FP 342 presently do not have unfired clay adhering to their undersides, although Robinson may have been describing their calcareous accretions.

Table 5.1 A hypothetical forming sequence for regular Protocorinthian tiles at Corinth inferred from surface markings

Primary Forming (above, Figure 5.7)	
1.	Each tile is formed right-side-up on a base mold. In preparation for packing with clay, a parting agent composed of the same mudstone used to temper the clay is sprinkled over the mold.
2.	The upper surface of a tile is shaped in an open-topped form with templates at its sides. After clay is packed into this frame, the top profile of the tile is trimmed down with a straightedge between the pair of profile templates at the front and the back.
3.	The template frame is removed after the top surface has been formed. The sides of the tile could first have been cut free from the frame by running a blade across the edges, or else the tile could be trimmed to the desired overall length and depth after the frames are removed.

Secondary Forming and Surface Finishing (above, Figure 5.15)	
4.	A notch is cut into one end of the cover soon after the primary formation has completed. Its location determines the handedness and orientation of the tile, because it always appears on the back side of the finished tile.
5.	All surfaces of the tile visible on the assembled roof are slipped and smoothed: the top, the front, and both sides of the cover.
6.	A pair of corner bevels is cut into the clay by the time it has turned leather hard.
7.	After the tile has dried sufficiently to be removed from the base mold intact, it is lifted off the mold, and rabbets are cut in the underside.
8.	Some tiles are coated with a dark paint.
9.	Setting guidelines are incised along the back and sides of the upper surface once the clay has dried leather hard and after any paint has been applied.

Post-Firing Modifications	
10.	All tiles are heavily retooled along the overlapping edges in order to create a tight joint with neighboring tiles.

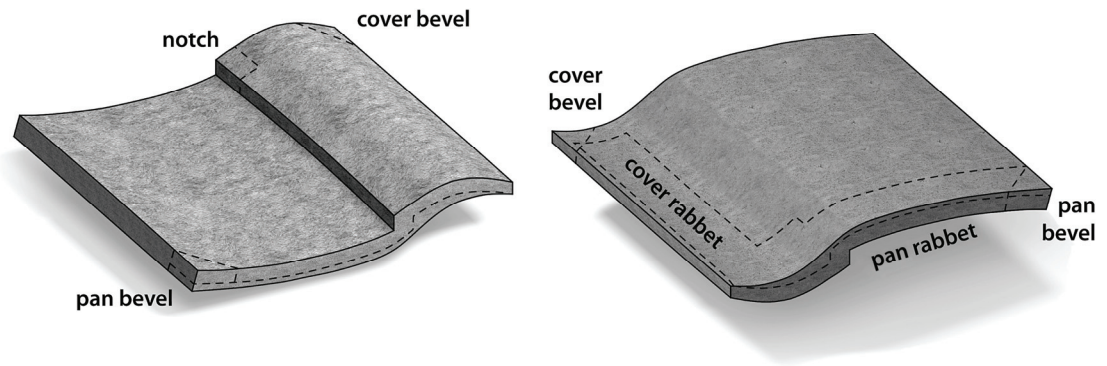


Figure 5.15 Top and bottom of a Protocorinthian tile after primary forming, showing the volumes to be trimmed away in later operations (dashed lines).

5.D) Hypothesis for the forming and finishing sequence

Based on the surface markings considered to this point, it is possible to propose a hypothetical forming sequence for testing by making replica tiles (Table 5.1). The inferences from the surface markings provide a relatively concise sequence of events, although the apparent order of stages 4 to 6 in the table varies from tile to tile.

CHAPTER 6: REPLICATION EXPERIMENTS AT ANCIENT CORINTH³¹³

6.A) Sources of raw materials

The first problem to be addressed here is the source for raw materials. The Protocorinthian tile fabric is a relatively fine clay with coarse tempering. Angular and subangular platy particles of mudstone and mudstone breccias that had been crushed or sifted to a maximum dimension of less than 4 mm occupy approximately 15-25% of the cross section (above, Figure 5.2). The clay color varies from pink to yellow, and refiring tests turned the clay yellow.³¹⁴

A fabric of yellow-firing clays and mudstone temper is common in Corinthian ceramics such as Type A' amphoras, perirrhanteria, architectural terracottas, and some architectural sculpture.³¹⁵ Exposures of mudstones are common throughout southern Greece, and a prominent deposit which outcrops in two places on Acrocorinth is usually identified as the source for the Corinthian temper.³¹⁶ Other exposures are found about 1 km to the west of the limestone outcrop under the Penteskouphia castle (Figure 6.1).

³¹³ In this chapter I describe the collaborative replication experiments conducted at Corinth in the summers of 2004, 2006, and 2007. In the plural voice I refer to Guy Sanders, John Lambert, and myself. I headed the project as principal investigator of the ancient Protocorinthian tiles. I received critical encouragement and support from Guy Sanders, who not only made the project possible by providing a workplace, tools, and transportation but also generously shared his time and knowledge of the local geology, clay deposits, and techniques for mixing and firing clays. When we realized that the tile replicas were too large to fire in a conventional kiln, Guy Sanders and Robin Rhodes, director of the Greek Architecture Project at Corinth, cooperated to finance the construction of the experimental kiln in 2006. John Lambert, an MFA who specializes in large-scale ceramic sculpture, was integral to the project from its beginning. He designed the frames and created dozens of replica tiles for the Snite exhibition at the University of Notre Dame (see above, note 1) both before and after working at Corinth as a member of the Greek Architecture Project at Corinth. He shared critical insights into fast and effective methods for mixing the local Corinthian clays and shaping the replica tiles, and in 2006 he designed and built the experimental kiln. We received the assistance of many others throughout the project, including Betsey Robinson, Ruth Siddall, and especially Allison Trdan.

³¹⁴ See below, note 355.

³¹⁵ Whitbread 1995, pp. 256-258, 268-278, 285-289, 294-300, 305-307. Also see Bookidis 2000, p. 387 and note 39; Weinberg 1957, p. 293-295.

³¹⁶ Farnsworth 1964, p. 224; 1970, pp. 10-11; Farnsworth, Perlman, and Asaro 1977, p. 456; Weinberg 1957, p. 295; Whitbread 1995, pp. 334-335; 2003, p. 6.

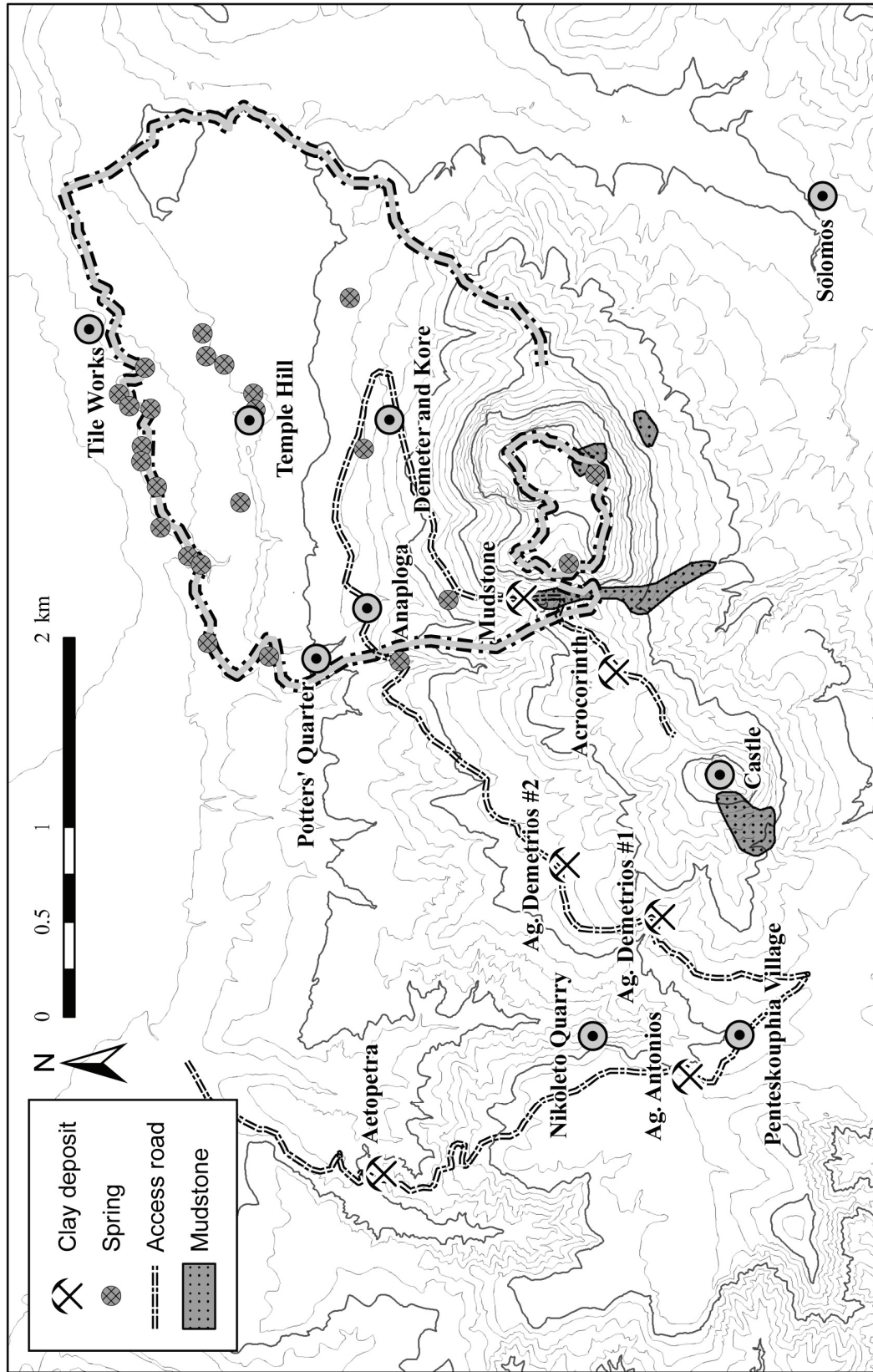


Figure 6.1 Resources for tile production in the Corinthia

6.A.1) Sources of clay in the Corinthia

Clays are abundant in the Corinthia, but a definite location for yellow-firing clay that matches the ancient pottery satisfactorily has eluded archaeologists. With the exception of Acrocorinth, Farnsworth found the lime content too high to withstand firing in the marl clays she sampled around the settlement of Corinth.³¹⁷ Brickyards at Solomos to the south of Acrocorinth mined a clay that was used successfully by the researchers at Isthmia to produce and fire replicas of Protocorinthian tiles (Figure 6.1).³¹⁸ However, other compositional tests have established that these clays do not resemble the fabrics of Archaic tiles or Type A amphoras.³¹⁹ Whitbread has published the most extensive research on the suitability of Corinthian clay deposits to date.³²⁰ Like Farnsworth, he found only calcareous clays on the terraces around Ancient Corinth itself.³²¹ To the southwest of the settlement, however, he collected clays with a lower calcite-quartz index near the village of Anaploga several hundred meters south of the Potters' Quarter. Excavated from the banks of a dirt track running west from Anaploga to Penteskouphia village, most of the clays were yellow firing and suitable for potting.³²² Whitbread also tested clays in contact with lignite seams at the quarry of Nikoleta to the north of Penteskouphia village, Solomos, and at a brick factory at Aghois Charalambos beyond Assos (Figure 6.1). Due to their proximity to lignite beds, their higher contents of kaolinite, and the reduction of calcite, the clays were workable, strong, and refractory in comparison to the others in the Corinthia.³²³

³¹⁷ Farnsworth 1970, pp. 19-20; Farnsworth, Perlman, and Asaro 1977, pp. 459-461; Jones 1986, p. 50.

³¹⁸ Rostoker and Gebhard 1981, pp. 226-227.

³¹⁹ Farnsworth, Perlman, and Asaro 1977, p. 460; Jones 1986, p. 179 and fig. 3.20a; Whitbread 1995, p. 312.

³²⁰ Whitbread 1995, pp. 308-346; 2003.

³²¹ Whitbread 1995, pp. 318-323.

³²² Whitbread 1995, pp. 314-317.

³²³ Whitbread 1995, pp. 324-329.



Figure 6.2 Penteskouphia plaques depicting clay mining (*above*) Berlin, Staatliche Museen 871B (Noble 1988, figure 75); (*below left*) Berlin, Antikenmuseum F 638 and (*below right*) F 639 (Xatzedemetriou 2003, plate 3, K11-K12)



Although generally resembling the yellow-firing fabrics in composition, the clay deposits around the site of Ancient Corinth, from the National Road, and at the Tile Works to the east of the settlement were unable to withstand normal firing tests due to their high calcite content. Clays mined at the foot of the slope below the Potters' Quarter were similarly flawed.³²⁴ Thus, Whitbread favors the lignite clay deposits as a probable ancient source. When fired, the clay from Nikoleta closely resembles the Type A' class 2 amphora fabrics in thin section. Furthermore, previous compositional tests reported 11.5% to 18.5% calcite in nearby clays from Aetopetra, a typical range for ancient Corinthian pottery.³²⁵ However, the Anaploga clays were also similar.³²⁶ At the present state of evidence, the clay deposits to the west and southwest of the site below the Acrocorinth-Penteskouphia saddle most closely resemble the compositions of the ancient pottery and tiles. Also in this region was the findspot of the Penteskouphia plaques famous for including many depictions of kilns, potting, and what is almost certainly clay mining (Figure 6.2).³²⁷

Working with calcareous clays would not have presented an insurmountable obstacle to ancient potters. Firing drives calcium carbonate (CaCO_3) into calcium oxide (CaO) while releasing carbon dioxide ($\text{CaCO}_3 \rightarrow \text{CaO} + \text{CO}_2$). Calcium oxide is hygroscopic, meaning it gradually absorbs water from the atmosphere and expands. Nodules of calcite at the surface of a vessel cause spalling, and, if they are mixed throughout the fabric at high concentrations, the expansion will weaken and eventually shatter a vessel in the days or weeks after it is fired.³²⁸ Modern Mediterranean potters

³²⁴ Whitbread 1995, pp. 339-341.

³²⁵ Vandiver and Koehler 1986, pp. 205-206; Newton et al. 1988.; Whitbread 1995, pp. 341-342; 2003, pp. 10-11.

³²⁶ Whitbread 1995, pp. 336-339.

³²⁷ Recent discussion of these plaques with earlier bibliography: Hasaki 2002, pp. 31-47, 434-452; Papadopoulos 2003, pp. 6-20, especially p. 9 notes 34-35. On the plaques indicating nearby pottery production: Hasaki 2002, pp. 37-44; Whitbread 1995, p. 340; 2003, p. 5.

³²⁸ Cuomo di Caprio 1984, p. 76; Rice 1987, pp. 97-98.

are able to circumvent the problem in several ways. First, they may fire calcareous clays at low temperatures. Calcium carbonate begins to decompose between 537 and 650 °C, but the reaction does not occur quickly until reaching the equilibrium pressure of carbon dioxide gas at 887 to 900 °C.³²⁹ The kiln temperature must be sustained at 700 to 850 °C before a significant fraction of calcium carbonate decomposes. Less CaO forms if the kiln temperature does not exceed 750 °C for long, which is still sufficient to decompose most clay bodies. Second, the potters may add a small quantity of salt to the clay, often about 1% of the total volume, which counteracts spalling.³³⁰ Mediterranean potters in Italy, Spain, and Tunisia mixed salts in their clays, although they named other reasons than spalling to justify the practice.³³¹ Third is a procedure called docking, where objects are soaked in water immediately after they are removed from the kiln. Besides brick makers, potters in Spain and Cretan potters from Thrapsano docked large storage jars after firing specifically to prevent lime spalling.³³²

Corinthians may have been able to fire the Anaploga and Penteskouphia clays without resorting to any of these methods. Although calcium is present at 10% to 30% in various deposits, tests have not indicated the size of the calcium-bearing particles. Large particles of calcium oxide are the most destructive, whereas fine, evenly dispersed particles may not be harmful.³³³ The reduction firing required for ancient black gloss pottery naturally slows the decomposition of calcite as well. The reaction

³²⁹ Jones 1986, pp. 753-754; Rice 1987, p. 98.

³³⁰ Butterworth 1956, pp. 538-540, Klemptner and Johnson 1985, 1986; Laird and Worcester 1956; Rye 1976, pp. 120-135.

³³¹ Spain: Vossen 1984, pp. 352-354 (Agost). Tunisia: Cintas 1949, p. 28 note 92 (Nabeul); Combès and Louis 1967, p. 40 (Djerba). Italy: Hampe and Winter 1965, pp. 106 (Valdérice), 113 (Delia), 114 (Niscemi), 117-118 (Vittoria), 176; Smith and Gnudi 1943, p. 219. Also see Rice 1987, pp. 119, 123.

³³² Butterworth 1956, p. 534; Klemptner and Johnson 1986, pp. 252-253. Docking in practice in Crete: Hampe and Winter 1962, pp. 15, 45, 91, 113. Spain: Vossen 1972, p. 40. Alternative methods for controlling calcite were developed in the prehistoric Americas: Feathers 2006; Klemptner and Johnson 1985, 1986.

³³³ Vandiver and Koehler 1986, p. 205.

into CaO is driven by the partial pressure of carbon dioxide, some of which is replaced with carbon monoxide (CO) in a reducing atmosphere.³³⁴ In fact, the atmosphere in any traditional wood-fired Mediterranean kiln will tend to become reducing as temperatures rise, because more oxygen is required to sustain combustion than can be supplied by the normal draft. Without forcing fresh air into the firing chamber, the amount of CO released by the fuel increases, the kiln enters a reduction phase, and calcium decomposition is stalled until about 800 °C.³³⁵

In conclusion, the difficulties of firing terracottas with calcareous clays in Corinth must have been overcome by fine ware potters despite the negative results of the initial tests by Farnsworth. We gathered clays for the replication experiments from a variety of promising modern outcrops to the west and southwest of the site to determine how workable a paste they formed and whether they could survive a low-temperature firing.

6.A.2) *Acquiring raw materials for the experiments*

Following the techniques of previous experimenters, we mined clays from known sources. Guy Sanders had identified several kiln sites from surface scatters of misfired fragments, so we collected near two of these sites (Figure 6.1). We also took clays from two outcrops between Penteskouphia village and Aetopetra exposed in road cuts. Although the exact locations are unlikely to have been exploited in antiquity, at least some ancient Corinthian potters may have used very similar deposits.

Rather than attempting to simulate traditional transportation techniques, we drove a car along modern tracks to gather materials. Consequently, any attempt to estimate the labor needed to acquire and transport clay must be based on ethnographic

³³⁴ See above, note 329.

³³⁵ Cuomo di Caprio 1984, pp. 76-77; Echallier and Montagu 1985, p. 144; Feathers 2006, p. 119.



Figure 6.3 Shoveling clay into baskets (Agios Demetrios site)



Figure 6.4 View from the Acrocorinth clay site to SW

sources instead. We cut the clay with small picks from the excavations, gathering at least 30 liters (0.03 m^3) at a time in large rubber baskets (Figure 6.3). The compaction of secondary clay deposits and seams along natural beddings, joints, and cleavages in primary deposits of clay greatly affects the rate of extraction. A soft fill or a highly fractured outcrop of clay is desirable because we could fill the basket two or three times faster there than at a resistant deposit. Two people could mine and load at least 3 liters of clay per minute from a loose deposit, approximately 0.18 m^3 an hour.

We gathered the first clay on the saddle connecting Acrocorinth to Penteskouphi castle. Scatters of wasters in the area suggest a medieval kiln was active in the vicinity. The “Acrocorinth clay” is pale yellow (2.5Y 7/3), fine, and moderately free from pebbles and roots, although it appears to be a secondary deposit from the talus under a limestone outcrop on the saddle (Figure 6.4). The clay is relatively loose, making it easy to mine, and it breaks down easily along cleavages into small, angular fragments about 2 to 4 mm across. Although the elevation of the site is 110 m higher than the others, it is within 600 m from the mudstone outcrops on Acrocorinth.

We collected clays from several sites along the dirt track between Anaploga and Penteskouphia village near Whitbread's samples, another medieval kiln identified by Sanders, and the Agios Demetrios chapel. The "Agios Demetrios clays" are generally light yellowish brown (10YR to 2.5Y 6/4), fine, and impure. These unconsolidated argillaceous sediments are mixed with sand, small pebbles, and bits of lime, much of which could be detected only after the clays were wetted. Although the clays are easy to extract and are found at a low elevation very near the Potters' Quarter, they would need to be levigated before resembling the comparatively pure clay of Protocorinthian tiles. The labor to clean the impurities would probably offset any advantage from the ease of extraction and proximity to Corinth.

We mined a third clay from the road cut just north of the chapel of the abandoned village of Penteskouphia, not far from the Nikoleta quarry site visited by Whitbread (Figure 6.5). This "Agios Antonios clay" is pale yellow (2.5Y 8/4), very fine, and came from a clean, consolidated deposit. It requires considerable effort to pick, although we could take advantage of joints and cleavages to break loose large blocks of the material at once. Once freed, the clay can be pounded into nodules 1 to 2 cm across which formed a workable paste quickly when wetted.



Figure 6.5 View to the SE (Ag. Antonios chapel to left; clays in scarp to right)

The fourth site is downhill to the north on the road cut near Aetopetra. Pale yellow as the Acrocorinth clay, the “Aetopetra clay” is very fine. The deposit is clean and consolidated. In places, it is soft enough to mine rapidly, breaking along joints and cleavages into small fragments. When wetted the clay quickly forms an excellent, workable paste that is noticeably more sticky and plastic than any of the other clays.

We collected mudstone from the road cut half a kilometer to the north of the entrance gates of the castle. Although the primary deposits are difficult to mine directly, a talus of loose angular particles, the majority 1 to 5 mm across, have accumulated from weathering of the bedrock. The loose fragments can be gathered with a shovel, although material from other sedimentary deposits is mixed in with the mudstone.

We produced test bricks from each of the clays with varying amounts of mudstone to determine the effects of firing each type, and we created replica Protocorinthian tiles from the Acrocorinth and Agios Antonios clays. As described below, we found that all the clays could survive a low-temperature firing which peaked below 800 °C. The clays most suitable for fabricating tiles turned out to be those from Agios Antonios and Aetopetra, both of which form a workable paste less prone to cracking during the critical period of early drying when a tile contracts most rapidly. We did not attempt to mix different clays. Although potters often mix clays to create an optimal clay body for hand building or throwing vessels, traditionally brick makers work with such large volumes that they typically do not mine clays from several areas.³³⁶ The nearby findspots for the Penteskouphia plaques indicate that the areas 3 to 4 km west of the center of Corinth may have been sites for Archaic pottery

³³⁶ However, Jones reports that about half of the 35 modern brickworks in Greece he surveyed mixed clays: Jones 1986, p. 52. It is unclear whether they exploited modern transportation networks and mixing machinery.

production (Figure 6.1). Controlled laboratory tests for the physical, chemical, and firing properties of the clays are planned but have not yet been performed.³³⁷

6.B) Paste and slip preparation

6.B.1) The worksite

We transported the clays and mudstone to a small open yard for the replication experiments (below, Figure 6.6). The ancient facilities would have been larger in order to attempt production on a scale for a full roof, but the modern yard was adequate for a small number of replicas. Besides open, well-ventilated areas in both the sun and shade useful for drying clay and objects, there is an enclosed shed for holding wedged clays and drying objects temporarily.

Rather than mixing large quantities of clay by treading it in pits, we prepared the paste in two wash basins hollowed out from large blocks of oolitic limestone (poros). The basins are particularly effective for mixing clay because the poros reduces drying time by leaching moisture from the clay, and there is no risk of contaminating the paste with soil from the walls of a pit dug directly into the marl-rich soil. Similar basins are found at the Archaic phase of the Greek Tile works at Corinth.³³⁸ However, when we measured exact volumes of dry materials, we used a plastic bin instead so none of the paste could escape.

We broke up the freshly mined clay and wedged the paste on a cement patio (Figure 6.6). A beaten earth floor would have served the purpose just as well and is common in ethnographic studies of traditional pottery and brick workshops. At

³³⁷ In collaboration with Albert Ammerman, Federica Bondioli, and Tiziano Manfredini as part of the *Study of Early Tiles in Rome* project. Samples will be analyzed at the University of Modena by X-ray diffraction, Tg-DTA, dilatometry, and laser granulometry.

³³⁸ Merker 2006, p. 9.



Figure 6.6 The worksite for the replication experiments: (left) overview and (right) clay drying on the patio next to the poros mixing basin

Poggio Civitate, the unwallled, colonnaded workshop that burned around 600 B.C. had a packed plaster floor where roof tiles had been laid out to dry.³³⁹

6.B.2) *Processing raw materials*

The paste is a simple mixture of clay and mudstone. Because the clay could not be efficiently measured after it was wetted and sticky, we measured out the materials by dry volumes. A fired fabric with about 20% to 25% mudstone in cross section corresponded to one part mudstone and about five or six parts dry clay, because the clay shrinks when wetted, dried, and fired, whereas the mudstone remains inert. The ratio can be established using pre-measured canisters to scoop clay and mudstone into a mixing basin. Mudstone is easiest to mix thoroughly into the clay before water is

³³⁹ Nielsen 1987, p. 91.



Figure 6.7 The *kopano* used for breaking up mined clay (Psaropoulou 1984, p. 13)

added. The ratios of clay, temper, and water are presented in the summary tables at the end of this chapter (below, Table 6.1).

The clays from Acrocorinth, Aetopetra, and Agios Antonios require little modification. After mining, the raw material was broken into nodules from 1 to 10 cm across. The Acrocorinth clays are a secondary deposit soft enough to be split apart by hand. The Aetopetra and Agios Antonios clays had been collected as hard, resistant fragments, some of which did not dissolve until soaked for several days. It is faster to spread the clay over the cement patio surface and beat the nodules down with a sledgehammer or a round stone pestle until they cleave into angular flakes less than 0.5 cm thick and 2.0 cm across. Below this size, the fragments dissolve into a workable paste after only a few minutes of soaking. The process is commonplace in Greece where clays are predominately stiff and calcareous. The standard tool to break up the nodules is the *kopano*, a branch sturdy enough for pounding clay (Figure 6.7).³⁴⁰ While beating the clay, we also removed stones and organic material, although the well-consolidated deposits at Aetopetra and Agios Antonios were generally clean.

The mixed clays from Agios Demetrios required extra cleaning. At a minimum, after beating them we ran the fragments through a coarse 4.5 mm screen, which captured most of the stones and roots. We dumped the larger clay nodules back onto the patio for a second round of pounding, and, after screening again, the majority of the clay mass was separated. The clays still contained smaller impurities, but they

³⁴⁰ e.g., Blitzer 1990, p. 680; Hampe and Winter 1962, p. 27, 62; Peacock 1982, p. 21.

were at least suitable for forming test bricks. We did not attempt to levigate these clays to remove the finer impurities.

Overall, preparing mudstone is more work than the clay, because sifting was unexpectedly labor intensive. The mudstone naturally cleaves along narrow fractures, and, after mining, a fraction of the material is already the size and shape of the temper in the Protocorinthian tile fabric. The majority of the temper fragments in the fabric in cross section have a maximum dimension of 1 to 4 mm. This consistency of size indicates that a screen with a maximum aperture of 2 or 3 mm may have been used to isolate the temper of the ancient tiles, so we used a 2.5 mm mesh.³⁴¹ Because smaller temper fragments are unusual in the ancient fabric, we also tried to screen out finer particles with a 0.5 mm mesh. We found that only about 60% of the mined material could fit through the coarse screen, and another 10% passed through the fine screen, leaving about half of the volume at the right size for tempering the fabric. We beat the remaining 40% coarse fraction with the stone pestle, but the mudstone was resilient and took more effort to break apart than the consolidated clays. Moreover, although we beat it against a concrete surface, the mudstone probably is too hard to break apart on a packed earth or plaster floor. Thus, it would have been more efficient to sieve mudstone at the quarry and discard the coarse fraction before carrying the remainder to the worksite.

6.B.3) *Mixing the paste*

After we crushed the raw materials to a desirable size, we mixed the clay and temper together in a stone basin (Figure 6.8). The batches of paste were small, sufficient only for the experiments of the day. Larger amounts could be measured out

³⁴¹ Some particles larger than the aperture will pass through a mesh, because elongated particles occasionally slip through.



Figure 6.8 Clay and mudstone are mixed in the basin before wetting

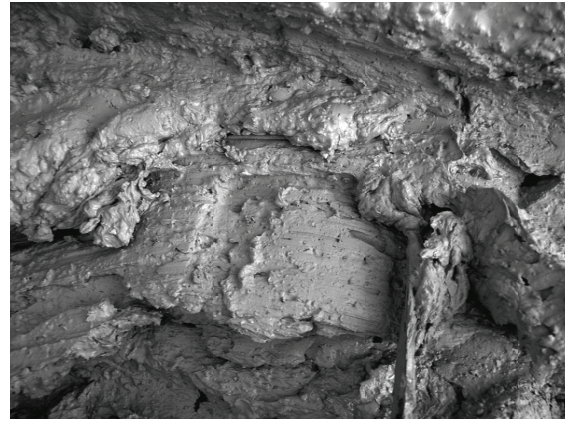


Figure 6.9 After mixing, the paste is too wet and sticky to hold its form

using one container of a fixed size, adding containers of clay and mudstone at the desired ratio. We stirred the dry mixture to distribute the temper evenly. Then we added just enough water to saturate the entire surface. Although we measured the quantity of water for most of the experiments, an ancient craftsman could simply add water until the clay developed the desired workability. No more refining of the clay is necessary. A tile maker does not need the series of settling basins that many potters use to purify slips and to refine clays for throwing.

We mixed the paste until it was evenly wetted. At first, we stirred it vigorously with a stake to bring water still pooled at the surface into pockets of light-colored dry clay. Because the clay fragments are small, they dissolve after only a few minutes in contact with water. Enough paste for one tile could be saturated evenly within 5 or 10 minutes. However, we continued kneading for approximately 15 to 25 minutes to break up a few stiffer nodules manually.

The resulting clay body has an excellent consistency, but it is too malleable to hold its shape and too sticky to smooth because any instrument touching the surface pulls up some of the clay (Figure 6.9). To stiffen the paste rapidly, we removed it from the basin and spread it to an even thickness of about 5 cm over the cement patio.

Water evaporates from the expanded surface area quickly in direct sunlight, and the cement underneath also absorbs moisture from the clay. The clay develops a dry skin and can be gathered and shaped within 20 to 40 minutes. Some wedging is still necessary to consolidate the paste and eliminate air pockets. We prepared too little material at one time to attempt the traditional Mediterranean method of treading the clay with bare feet. Instead, we gathered 3 to 6 kg of clay and dropped it a short distance onto the pavement 10 or 15 times. This oriented the clay and temper particles parallel to the patio surface, resulting in a rectangular slab about 5 to 10 cm thick that was ready to pack into the tile frame (below, Figure 6.10).

6.B.4) *Slip and paint*

In addition to the tempered fabric, Protocorinthian tiles also had a fine clay slip on their upper surfaces. In many cases, the slip layer and the body fabric are nearly indistinguishable, indicating that both were formed from the same source of clay.

A variety of techniques for preparing slip has been known since antiquity, but there is little hope of restoring the particular method used for these tiles. Thin-walled fine pottery might have been purified to the same degree as the tile slip, in which case the clay would have been refined in a series of settling tanks.³⁴² For the experiments, we prepared only a small amount of slip, enough to coat just one tile at a time. We pounded the clay on the patio and ran it through a fine 1.5-mm mesh. We stirred in water until the powder was completely saturated, and then the mixture was left to settle in the sun. A clear film of water rose to the top. We decanted it to expose an intermediate layer of creamy pure clay. The slip is best applied at a higher viscosity, so we allowed it to stiffen further and rewetted it slightly on the tile. An alternative method for controlling the viscosity that we did not attempt is sprinkling a stiff slip

³⁴² See, e.g., Echallier and Montagu 1985, p. 142.

mixer with a deflocculant such as wood ash, which would have rapidly thinned the viscous mixture.

During the experiments, we did not attempt to reproduce the black to reddish-brown paints found on one fifth of the Protocorinthian tiles.

6.C) Primary forming sequence

1. Each tile is formed right-side-up on a base mold. In preparation for packing with clay, a parting agent composed of the same mudstone used to temper the clay is sprinkled over the mold.

6.C.1) Producing the base mold

Because all Protocorinthian tiles have a curved underside formed on a mold, it is necessary to create the mold in advance of shaping the tile. The base could have been wood or even stone,³⁴³ but we designed it instead from clay. The advantages of using clay are that the mold requires no significant joinery or carving, it can be constructed from the most abundant material on the worksite, and it is shaped with the same technique as the upper surface of the tile. Small clay molds were used at Corinth at least as early as the mid-seventh century B.C., so the principle probably was familiar to ancient tile makers.³⁴⁴ As with the tile, we pulled a strike along a pair of templates to level the mass of clay. Moreover, although wood or stone bases are feasible for a normal combination tile, the complex molded curvatures on the undersides of eaves and hip tiles are more challenging to create in stone or wood. In particular, the smooth,

³⁴³ e.g., Rostoker and Gebhard 1981, pp. 220-221. John Lambert designed wooden molds to form the replica Protocorinthian tiles for the Snite exhibition at Notre Dame, IN: see above, note 1.

³⁴⁴ A few small figurine molds were found in seventh-century contexts at the Potters' Quarter at Corinth, although none of the contexts date as early as the Old Temple. Fragments of six female and male head molds are dated to the seventh century (nos. 1 to 6): Stillwell 1948, pp. 87-90. The majority are dated to the third or fourth quarters of the century, but no. 1, despite being recovered with pottery dating to the third quarter of the century, was dated "at least as early as the early seventh century" on the basis of stylistic parallels to Near Eastern heads from the eighth and seventh centuries: Stillwell 1948, pp. 87-88. Also see Gebhard 2001, pp. 58-59; and below, note 547.



Figure 6.10 Wedging a slab of clay by dropping it onto a layer of mudstone



Figure 6.11 The first layer of clay packed in the base mold

three-dimensional transition on the underside of the eaves tile suggests that its shape was cut from a solid mass of clay (above, Figure 3.11).³⁴⁵

Because the base mold is formed with the same technique as was used for the tile, the description here of the template system and the striking of the base mold is abbreviated. We prepared a four-sided wood frame with the underside profile of a tile at the front and back faces. We set the frame on a moveable platform so we would later be able to carry a tile on its base around the worksite (Figure 6.11). The frame is a full 72-cm square, slightly larger than the finished tiles, to allow for some trimming and shrinkage from drying. We prepared a large batch of tempered clay to fill it. The thickness of the mold was irregular, at the maximum about 10 cm below the cover, tapering to a minimum of about 5 cm at the cover-pan joint of the tile, and gradually rising to 8 cm at the free end of the pan. During preliminary experiments in 2004, the clay adhered to the platform below as it shrank, so the first mold pulled apart at its thinnest point below the cover-pan joint. To counteract this tendency, we laid a thick bedding of temper on the platform that permitted the mold clay to shrink freely, and

³⁴⁵ See below, p. 286f.

we filled the whole area of the mold with a large slab of uniform thickness (Figure 6.11). After leaving the bottom slab for a short time to dry, we packed slabs of clay into the frame until it was filled to within approximately 1 cm of the upper edge of the template frame.

The first clay base mold from 2004 was prone to breaking along its upper edges during the later forming and manipulation of the tile. Although these breaks could be patched up with fresh clay, we decided to stiffen the upper layer of the second-generation base mold instead. For the uppermost centimeter of the mold, we mixed the tempered paste with one eighth part Portland cement. The cement was no obstacle because we did not intend to fire the base mold. We found that the cement reduced the plasticity of the clay body, but it was still possible to fill the remainder of the base mold and to strike the upper surface carefully. Within a few hours, the upper surface of the mold became solid.

If this had been the ancient technique as well, lime mortar would have been used instead of cement. Because lime mortars were the standard surfacing for mud-brick vernacular architecture in antiquity, it is plausible that the tile makers would have developed this solution if they had indeed made clay base molds. An alternative, however, is simply to fire the base mold at a temperature low enough to avoid cracking but high enough to solidify it throughout. Not only would the whole mold become harder than mortar, but also it would be lighter, sturdier, and thus easier to manipulate. The technology was known at the time. Although much smaller, the clay molds surviving from Archaic Corinth were also fired. We did not fire the base mold during the replication experiments because firing the kiln was difficult and time consuming, and the cement mixture solidified the mold adequately to produce at least several tiles.

6.C.2) Preparing for molding a tile

2a. The upper surface of a tile is shaped in an open-topped form with templates at its sides.

The base had dried within two days, but we left it to cure for a week. The mold had shrunk to a 70-cm square, which still left a few more centimeters of shrinkage for the replica tile itself. We prepared four wooden boards to frame the tile. The front and back boards were templates for the top curvature, with curves for the cover and pan and a vertical offset at the cover-pan joint (below, Figure 6.12). Two straight boards ran along the other two edges, holding the templates in position and retaining the sides of the tile. We gently chiseled back the edges of the base mold so that it fit snugly within the frames. Instead of attempting any elaborate joinery which ancient Corinthian woodworkers might have used, we attached the frame with wood screws. When tightened around the base mold, the frame was immobilized, but it could be pulled away by loosening the screws at one corner.

We sprinkled a thin coat of temper to act as a separator layer keeping the tile from sticking to the mold. On the steep slope between the cover and pan, the temper slid down and accumulated at the base of the pan, so temper was unevenly distributed around the cover-pan joint (Figure 6.12). The same pattern is frequently observed on the ancient tiles.

6.C.3) Constructing the tile

2b. After packing clay into this frame, the top profile of the tile is trimmed down with a straightedge between the pair of profile templates at the front and the back.

With the mold in position and a stockpile of clay drying on the patio, construction could begin. We quickly prepared slabs of clay in the manner described above and packed them over the mold. We started at the corners and sides of the frame

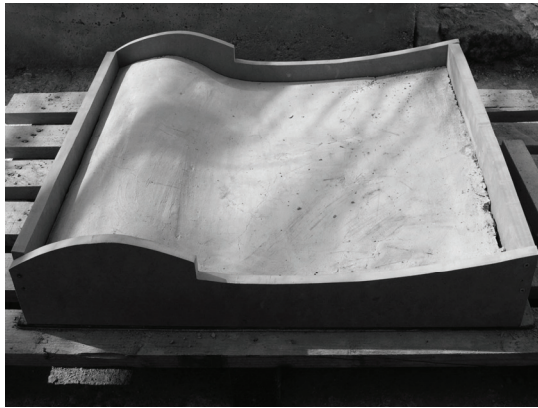


Figure 6.12 The base mold and template frames are ready to pack with clay **Figure 6.13 The first slabs are packed into the base mold**

in order to ensure that the edges were completely filled with clay (Figure 6.13). To minimize the seams between slabs we kneaded the clay with our fingertips. When the entire surface of the base mold was covered, we gently pounded the clay with an open palm to pack it down and eliminate air pockets. This gesture would have oriented the temper parallel to the base mold as well, which is common in the fabric of Protocorinthian tiles. About ten slabs, equivalent to 45 kg of wet paste, were sufficient to fill the mold over the top of the upper templates.

When the frames were filled with the paste, we leveled the surface by hand. Areas which appeared too high above the frame were patted down. We added patches of clay where the surface was still too low, which often happened at the edges of the frame and at the cover-pan joint (Figure 6.14).

6.C.4) *Striking the upper surface*

At this time, the surface was ready for striking. We gripped a straight board firmly in both hands and dragged its edge along the surface of the tile. By keeping the strike perpendicular to the front and back sides of the frame, the whole surface of the tile was cut exactly to the profile of the templates (Figure 6.14 and Figure 6.15).



Figure 6.14 First pass with the strike



Figure 6.15 Striations on top

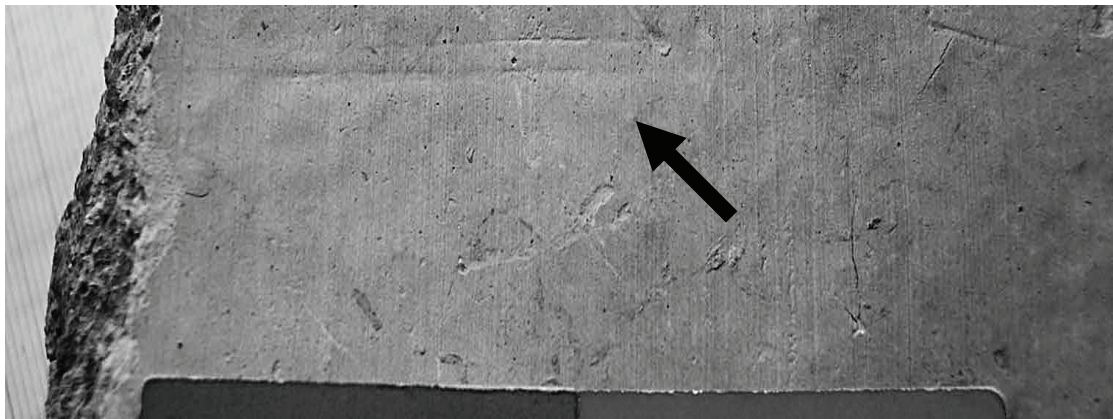


Figure 6.16 Groove under the slip, FC 29 (*6 cm scale card width*)



Figure 6.17 After striking the replica, the surface is smoothed with a trowel

Because the strike could not contact any clay below the level of the templates, it is essential for all parts of the mold to be slightly overfilled. During the striking experiments, many areas proved to be too low and needed to be patched. Too much excess paste, however, eventually becomes too resistant for striking. In that situation, we used a spatula to cut away small quantities of excess clay. Both problems would have become less common with experience.

The process was slow and required caution. The right consistency for the clay body was essential. If wet, it is malleable and easy to cut down, but it is so sticky that the strike pulls open gashes in the surface. If dry, it is so stiff that the strike cannot be pulled down to the level of the templates without excessive force. Such force opens gaping holes as wads of clay and temper are squeezed out from the surface. The most effective technique with moderately damp, sticky clay is to draw the strike gently over the tile. Leveling it requires repeated, short, slow strokes. Small quantities of clay are removed with each pass and accumulate on the edges of the board. This extra clay has a tendency to mar the surface of the tile, so it is necessary to clean the edges of the strike frequently. This excess can be wiped into gashes or other low areas revealed during the striking. Occasionally, fragments of temper caught by the smoothing board are dragged along the surface, leaving unsightly grooves that must be polished over with another pass or patched with a long roll of fresh clay. Particular care is needed at the cover-pan joint, where the sharp changes in angle must be shaped by several gentle strokes over each plane.

After about five to ten passes with the board, the surface was brought down to the level of the profile templates. Although the resulting surface was even, the strike left shallow striations along the length of the tile, parallel to the direction of the stroke (Figure 6.15). Most of the grooves are fine enough to rub away by hand. To remedy deeper grooves created by large fragments of temper or dried clay on the board, we

reworked the surface with the strike, this time pulling it diagonally across the groove in order to draw the adjacent clay into the cavity.

We found it difficult to achieve the degree of polish on the ancient tiles. Although the drag marks are too fine to have been seen on the finished roof, the majority of the ancient tiles are not noticeably grooved. The secondary slip coat usually is thick enough to conceal the original surface texture. However, in the handful of Protocorinthian tiles where the slip has split away from the fabric, the lower surface has narrow striations similar to the appearance of the replica tiles after their initial striking (above, Figure 5.4). A few other tiles in the Corinth museum whose slip is intact provide further evidence for the use of a strike. Occasionally a groove that is too wide to have been completely filled with slip is visible running parallel to the front and back faces of the tile (Figure 6.16).³⁴⁶ The ancient tile makers neglected to smooth these wider grooves which very likely had been caused by fragments of temper dragged along the upper surface by a strike.

When only fine longitudinal drag marks remained, we smoothed the upper surface from front to back with moistened fingers or else a metal trowel (Figure 6.17). The spatula quickly produced a very smooth surface, but it was difficult to use in places where the tile was curved. The spatula was most helpful for straightening and sharpening the vertical face at the cover-pan joint.

6.C.5) Completion of the primary forming sequence

3. *The template frame is removed after the top surface has been formed. The sides of the tile could first have been cut free from the frame by running a blade across the edges, or else the tile could be trimmed to the desired overall length and depth after the frames are removed.*

³⁴⁶ i.e., FC 29, FC 78, FC 79, FP 108.

Once the top surface was complete, we loosened the frames. In order to protect the edges of the tile, we first cut them loose with the blade of the spatula. The free end of the pan had been formed up against the vertical face of the frame. However, in Protocorinthian tiles this face had been cut back to an angle perpendicular to its bottom, so we trimmed away a strip of clay along this edge to shorten the pan slightly. The full length of the pan is relatively variable in the ancient specimens, indicating this cut was not carefully measured but rather estimated relative to the edge of the frame. Then we removed the frame. The blade had caught and dragged some pieces of temper in the fabric along the side faces, leaving a few grooves similar to those on the unslipped back faces and free edges of the pan in Protocorinthian tiles.

We had deliberately molded the longitudinal dimension of the cover larger than was strictly necessary, because the side face of the cover generally is difficult to shape precisely in the mold frame. After the frame was removed, the upper free corner of the cover had not been sharply profiled. Using a straightedge, we surveyed the correct length for the cover and cut away a narrow strip along its free end, creating a sharp transition to the vertical face.

At this stage, the primary forming is concluded. The basic mass of the tile is profiled, and future stages of manufacturing are either subtractive or surface finishes. The tile paste is still very damp and cannot yet be removed from the mold. Because several operations in the secondary forming sequence take place while the clay is still damp, the work continues without pause.

6.D) Secondary forming sequence and surface modification

4. A notch is cut into one end of the cover soon after the primary formation has completed. Its location determines the handedness and orientation of the tile, because it always appears on the back side of the finished tile.



Figure 6.18 Cutting the notch



Figure 6.19 Applying slip by hand

At this stage, the “handedness” of the tile is determined. Tiles can be both right and left handed, but either can be created from only a single mold and template system. One face of the tile is designated as the front while the opposite becomes the back, and the notch, corner bevels, and underside rabbets are oriented accordingly (above, Figure 5.15). The first feature cut into most Protocorinthian tiles appears to have been the notch because smears of clay are often left on its faces, which indicate the paste was still very wet when it was tooled. We designated the back edge on the replica tile and cut the notch with a knife into the attached back corner of the cover. We produced left-handed tiles by placing the notch at the back right corner of the cover (Figure 6.18).

6.D.1) Application of the slip

5. All surfaces of the tile visible on the assembled roof are slipped and smoothed: the top, the front, and both sides of the cover.

For most ancient tiles, the slip was so well bonded that it appears to have been applied while the fabric was still very wet. The fragments whose slip had flaked away,

revealing striations on the surface underneath, had probably dried significantly before the slip was added. However, these cases are exceptional. Nevertheless, the slip had clearly been applied after the notch had been cut out from several tiles where excess slip was wiped over the faces of the notch (above, Figure 5.11). In most cases, the original order is unclear, and probably there was some variation from tile to tile, with both the notch and slip coming soon after the primary forming.

In preparation for applying the slip, we retouched the side faces with the spatula and sharpened some of the upper edges. Then we poured a handful of slip onto the center of the tile and distributed it over the tile, smoothing the surface gently with moistened fingers (Figure 6.19). It is important for the slip to have a consistency similar to a heavy cream which is viscous enough to hold its shape. If the viscosity is too low, it is difficult to apply the coat of slip, which is often up to 1 mm thick on the ancient tiles. On the other hand, dried slip was difficult to spread over the surface, but it could be reconstituted quickly with a sprinkle of water.

Although Protocorinthian tiles have brush-like marks on their upper surfaces, we found while experimenting with a brush that its hairs tend to leave deep, harsh grooves in the soft clay. Smoothing by hand works better, and the grooves in our fingerprints leave faint ridges characteristic of an ancient tile's surface. It does not appear that the tile makers waited long to smooth the slip, because once the slip dries leather hard, further polishing produces a slight, glossy burnish unlike the matte slip on the ancient fragments. By applying slip and smoothing the surface soon after the tile was formed, we also ensured a tight bond to the tempered fabric of the tile, which minimized cracks in the slip caused by differential rates of drying and shrinkage.

Any impurities such as grains of sand or organic material in the slip interfere with the smoothing and are difficult to remove from the surface of the tile. It is possible to pull an isolated piece of grit away from the tile by drawing it to the edge

with a rapid transverse stroke of the hand. However, during this operation there is a tendency for other fragments of temper to be caught up and dragged along the surface, leaving a transverse groove in the slip that must be polished. The first slips we prepared were inadequately cleaned, and the smoothing process could require excessive time as it extended for 20 or 30 minutes to prepare a satisfactory surface. Preparing a well-purified slip instead is worth the effort.

6.D.2) Corner bevels and drying

6. A pair of corner bevels is cut into the clay by the time it has become leather hard.

Finally, bevels are cut on the diagonally opposite corners of the tile, at the front free corner of the pan and the back free corner of the cover (above, Figure 3.9). Because the corner bevels on the ancient tiles have frequently been retooled, it is often difficult to determine at what point during the production sequence they were cut. In the replication experiments, we cut the corner bevels with the spatula immediately after the slip was applied.

At this time, the tile must dry before the work can continue (below, Figure 6.20). The tile paste has dried noticeably since the frames were removed. The polishing and reworking of the surface had somewhat accelerated the evaporation, but the tile is still completely incapable of supporting its own weight. Although it might have been lifted off its bedding with an apparatus to allow cutting the underside rabbets immediately, no impressions of a such a device are preserved on any Protocorinthian tiles.³⁴⁷ As with our replicas, the ancient tiles probably remained on

³⁴⁷ John Lambert experimented with such an apparatus for the Protocorinthian tile replicas he fabricated for the Snite exhibition at the University of Notre Dame, Indiana. See above, note 1. He constructed the base mold for the tile out of wood, but he also created a separate, interlocking mold in the shape of the upper surface of the tile. After forming the tile normally on the base mold and leaving it to dry for a short time, he set the interlocking frame over the tile and flipped the apparatus so the tile was supported upside-down on the top mold. Not only could Lambert cut the underside rabbets, but also the apparatus



Figure 6.20 The completed replica tile is left to dry after the bevels are cut

the bottom mold until they had stiffened. Left in the heat of a Corinthian summer, they could dry leather hard within 6 hours even in the shade. At this stage, we could nudge the whole tile around the base mold, showing that the parting agent had effectively kept it from sticking. We could test when the tile was ready to remove by gently pressing on its edges, sometimes leaving fingerprints similar to those preserved on several Protocorinthian tiles (above, Figure 5.10).³⁴⁸

The amount of time before the tile was strong enough to remove from the mold varied with the weather. The rate of drying slowed during the night. While it is conceivable that a tile completed early in the morning would have time to stiffen enough to remove it from the mold by evening, we finished no replica tile before afternoon and instead left each tile to dry overnight. By the following afternoon, the

gave him more control of the drying process. However, such a system is unlikely to have been used for Protocorinthian tiles because the base mold was probably in clay, no markings from a top mold are preserved on any of the fragments, and the apparatus prevented Lambert from applying the slip as early in the forming sequence as indicated by the ancient tiles.

³⁴⁸ See above, note 305.

tile was quite strong, and, after another day, it had become so stiff that cutting the underside rabbets was difficult. Under optimal conditions, a tile could have been ready to move after only 6 to 8 hours, but, in many cases, tiles would have needed to be left overnight on the base mold for a total of 16 to 24 hours. These figures would apply only during the dry heat from late Spring through Fall, and even then the work would have been impeded by humid, overcast, or rainy days.³⁴⁹

6.D.3) Leather-hard modifications

7. After the tile has dried sufficiently to be removed from the base mold intact, it is lifted off the mold, and rabbets are cut in the underside.

After the clay has dried leather hard, it is no longer able to bend. If pressing its sides with our fingers shifts the tile rather than indenting the faces, it is ready to lift from the mold. The separator layer of mudstone had successfully kept all our replica tiles from sticking to the mold, so it was easy to slide the tile off the base. After we had freed its front half, we could grasp the tile at the thickest areas to raise it. The replica was still extremely heavy, but two people could move it safely. We stood the tile on its back end and leaned its top edge against a wall in order to cut out the cover rabbet on the underside (Figure 6.21).

Because the clay was relatively stiff and resistant, the cover rabbet was difficult to cut consistently. The rabbets clearly had not been molded into the bottom of the ancient tiles because their dimensions vary considerably. The pan rabbet at Corinth was chiseled out only after firing. We surveyed the inside edges of the rabbeted shelf first. With the spatula, we cut a shallow line into the front face of the tile marking the cover rabbet, and we cut a groove at its inside edge on the bottom. A

³⁴⁹ A replica hip tile that we produced in Indiana took four days to dry leather hard due to the humidity.



Figure 6.21 Surveying the rabbet on the bottom of the replica tile



Figure 6.22 Cutting the rabbet with a spatula

few survey lines have been preserved on the cover rabbets of several fragments from Corinth.³⁵⁰

We found the most efficient way to cut the rabbets was to peel off layers with the rectangular point of a spatula (Figure 6.21). Cutting in a transverse direction parallel to the side of the cover rabbet, we took the rabbet surface down to a desirable depth in several passes. The first cuts are the most difficult, but the clay in the interior is slightly damper and less resistant. In the end, we leveled the surface by drawing the spatula down the face in several parallel strokes, leaving a surface resembling the original tiles. The process is slow at first, but with experience we reduced the time considerably. However, it is advantageous to remove the tile from the base mold as soon as it is able to support itself, when the clay is easiest to cut.

8. Some tiles are coated with a dark paint.

³⁵⁰ i.e., FC 62, FC 86, FP 155, FT 210, FP 314.

9. Setting guidelines are incised along the back and sides of the upper surface once the clay has dried leather hard and after any paint has been applied.

We did not reproduce the black paint or setting guidelines on some Protocorinthian tiles. Both features appear to have been one of the last modifications to the tiles before firing.³⁵¹ We left the replica to dry in a sheltered space, and it was ready to fire within a week.

6.E) Test bricks for quantitative analysis

We also prepared a series of bricks to test the properties of the clays. Rather than manufacturing tiny test bars that are standard in laboratory analyses, we produced larger test bricks that resembled the proportions of the Protocorinthian tiles but which we could shape more quickly. Using the bricks, it was possible to create recipes for the proportions of clay, water, and temper in the paste; the shrinkage rates for each clay source with varying amounts of mudstone temper; and to experiment further with striking a brick in a simple, flat frame.

We built frames for two gauges of bricks. Small bricks were formed in a 25 x 25 x 3 cm frame containing 1.875 liters of clay, and large bricks in a 50 x 50 x 5 cm frame with a capacity of 12.5 liters. In contrast, the tile frame was filled with about 23 liters of paste, and, after the excess was discarded, the volume of the formed tile was about 18 liters.

We formed the bricks using a similar procedure as that applied to the Protocorinthian tiles, but we set the four-sided frame directly on the patio and sprinkled mudstone as a separator layer onto the surface. The clay body was prepared in plastic bins for more exact measurements, and we packed one slab of wedged paste into the small frames and several slabs into the large frames. We struck the upper

³⁵¹ See above, notes 306, 308, and 309.

surface quickly and unfastened the frame to release the brick. In the afternoon heat, the bricks stiffened enough to be moved in as little as one hour, although we generally waited 4 to 6 hours before moving the large bricks. Despite drying very quickly, the bricks did not crack from shrinkage. Only two were damaged from handling, although several more large bricks sheared while we were loading the kiln because we inadvertently stacked too much weight on them. Many of the bricks were bone dry within 48 to 72 hours.

The data from the experimental bricks are analyzed further below.

6.F) Ancient and experimental firing

6.F.1) *Ancient firing conditions*

The original firing temperature for the Protocorinthian tiles cannot be reliably estimated without further analyses,³⁵² but some general observations may be made.

The clay color varies from pink (5YR 7/4) to yellow (2.5Y 8/6), but when exposed in the break faces, five sixths of the tiles have a reddish interior that ranged from pink (5YR 7/4) to reddish yellow (7.5YR 7/6).³⁵³ The dark-painted tiles are not fired to a uniform color. Although the paint has fired to a uniform dark tone on some tiles from very dark gray (2.5Y3/1) to dark gray (5YR4/1), more than half of the tiles have patches of reddish-brown, either in irregular splotches, in areas where the paint looks thin, or else over the majority of the surface. The most intense areas of these paints developed a reddish-yellow (7.5YR 6/6) to red (2.5YR 5/8) color. A small number of unpainted tiles are distinctly more yellow in comparison to the others, their fabrics pale yellow (2.5Y 8/2) to yellow (5Y 8/4) throughout and without any reddening in the interior.³⁵⁴ These variations seem to have been related to the

³⁵² e.g., Rice 1987, pp. 426-435.

³⁵³ See above, note 298.

³⁵⁴ i.e., FC 65, FP 107, FC 111, FC 114, FP 309, FP 334.

temperature of firing rather than a different clay body because the mudstone temper in these tiles is dark gray instead of the normal reddish brown. Moreover, one fragment, FC 65, has patches with a glassy, bloated surface that, unique among the Protocorinthian tiles, was an olive (5Y 5/3) color. Finally, when Whitbread refired samples from several tiles to 1,100 °C for three hours in an oxidizing atmosphere, the fabric became pale yellow (2.5Y 7/5) to olive yellow (2.5Y 6/6).³⁵⁵ Thus, as with most calcareous clays, the Protocorinthian tile fabric becomes increasingly yellow with rising temperatures in the range of 800 to 1,100 °C.³⁵⁶

The unpainted tiles are pink to yellow, suggesting variations in temperature, atmosphere, and perhaps the source clays. The colors of the tiles are similar to Whitbread's samples from clay beds nearby the Tile Works, Anaploga, and the Nikoleta lignite quarry. The modern clays turned pink (7.5YR 7/4), reddish yellow (5YR 6/6), and very pale brown (10YR 7/4) after firing 3 hours in an oxidizing atmosphere at 700 °C.³⁵⁷ The samples fired to 1,100 °C turned pale yellow (2.5Y 8/4 or 5Y 7/3), and those fired to 900 °C fell either in one group or the other. Whitbread's clays from other sites around Corinth did not resemble the color range of the tiles.³⁵⁸

The colors of the ancient dark paints may indicate an imperfect control of firing conditions. The intent seems to have been to produce an even black for the dark paints, but most have irregular splotches of red, which must be the result of variations in the mixture and thickness of the paint and the firing conditions. Although manganese might have been used as an additional coloring agent, the abrupt

³⁵⁵ i.e., FP104, FP107, FP109, FR105: Whitbread 1995, p. 294; 2003, p. 9. Of the four tiles, FP104 and FP109 certainly belonged to the Old Temple, while FP107 and FR105 likely belonged to the Old Temple roof.

³⁵⁶ Jones 1986, pp. 759. Naturally occurring salts may heighten the effect: Matson 1971, pp. 66-67; Rye 1976, p. 122.

³⁵⁷ Whitbread 1995, p. 316 table 5.5 (samples 1-4); pp. 321-322 table 5.7 (samples 6, 11-12); p. 326 table 5.9 (sample 21).

³⁵⁸ Whitbread 1995, pp. 321-323 table 5.7 (samples 7-10, 13-16); p. 332 table 5.11 (samples 3, 20, 28-29).

fluctuations between dark gray and red suggest that iron compounds are responsible for at least some of the variation.³⁵⁹ Besides variations in the slip itself, black does not form if the temperature in the kiln is not sustained above at least 800 °C in a strong reducing atmosphere.³⁶⁰ Although wood-fired updraft kilns tend to develop a reducing atmosphere at higher temperatures,³⁶¹ it is possible that the reddened paints had not been fired above 800 °C for enough time.

Only six ancient tiles have been fired yellow throughout, and FC 65 has partially vitrified, indicating that it had been heated more than any other tile. Given the characteristics of Corinthian clays, it is probable that FC 65 was subjected to heat in excess of 1,100 °C, while the other pale tiles were heated between 900 and 1,100 °C. It is very unlikely that tiles were regularly fired as high as 1,100 °C in antiquity. The six yellow tiles may have all come from an unusually hot kiln batch, although the temperature may vary significantly inside an updraft kiln.³⁶² The vitrified FC 65 may have been reheated in another fire. Comparing the color ranges found in Whitbread's firing tests to those of the Protocorinthian tiles, it is likely that the majority were fired at a maximum sustained temperature between 700 and 900 °C and only occasionally higher. However, over the several firing batches for the full roof, the peak temperatures would have varied.

We fired the experimental kiln in the lower range of possible temperatures in order to minimize calcite decomposition. We decided to soak the kiln at about 750 °C, holding it at least this temperature for close to an hour at the end of the firing (below, Figure 6.25).

³⁵⁹ See above, note 309.

³⁶⁰ Experimental studies with black gloss pottery suggest 800 °C is an absolute minimum, with a reduction in the range of 850 to 950 °C to ensure the sintering of the fine paint: Jones 1986, p. 804; Farnsworth and Wisely 1958, p. 166; Noble 1988, pp. 155-156.

³⁶¹ See above, note 335.

³⁶² e.g., Echaliér and Montagu 1985; Nicholson and Patterson 1989, pp. 80-82.

6.F.2) *The experimental kiln*

It was necessary to build a kiln to fire the replica tiles and test bricks. The full-sized tile is 65 cm square, too large for any of the conventional electric or gas kilns available in Corinth. We preferred to simulate the ancient atmosphere as closely as possible by firing wood and branch clippings. However, we adopted a modern design for a wood-fired kiln rather than attempting to build an authentic Mediterranean updraft kiln in mud brick. Such kilns have been constructed in experimental tests,³⁶³ and the type is well documented in the ethnographic record. Using a traditional kiln was unlikely to lead to significant new insights into the firing process of Protocorinthian tiles. As long as the fuels are similar, the results of the firing should be useful for comparison.

The experimental kiln is a horizontal-draft design, which combines the combustion and firing chambers into one elongated space (below, Figure 6.23). The combustion occurs at the front of the chamber, separated from direct contact with the wares by a perforated “bag wall.” Although some air flows through the perforations, most heat rises over the bag wall and down through the firing chamber to a vent on the floor at the back of the kiln. Thus, although the chamber is horizontal, the air flow may be likened to a down-draft kiln.

The horizontal design carries some advantages over the traditional updraft kiln.³⁶⁴ The fuel efficiency is somewhat higher because heat is not lost directly through the roof of the kiln. The structure is more stable because the wares are set directly on the ground instead of an elevated floor supported by lintel bricks. The kiln is also capable of sustaining high temperatures in excess of 1,300 °C, permitting future

³⁶³ e.g., Nicholson 1995; Rostoker and Gebhard 1981.

³⁶⁴ Cardew 2002, pp. 192- 194, 195-215; Rhodes 1968, pp. 18-35, 127-133; Rice 1987, pp. 159-161.

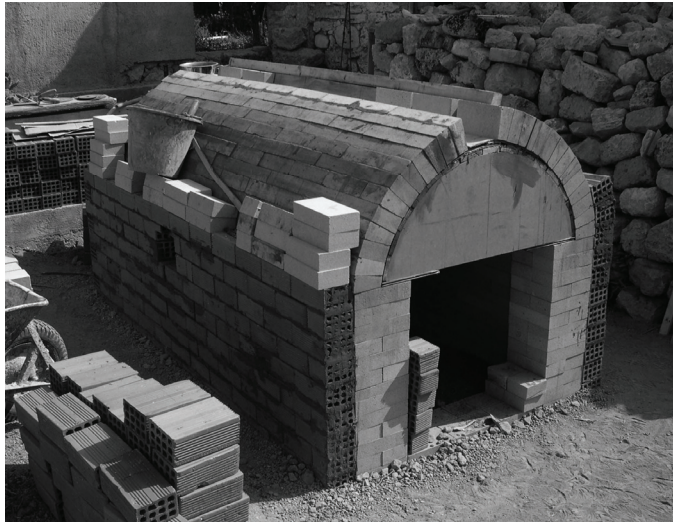


Figure 6.23 The experimental kiln during the construction of the vault



Figure 6.24 The completed kiln with the bag wall inside

experiments with high-fired ceramics. Its construction was expedient for our purposes because the whole chamber could be built with standard-sized refractory bricks.

We began by leveling the site for the kiln and laying bricks around its perimeter. The floor was coated with a thick layer of mudstone gravel, which has proven its refractory quality since antiquity. The chamber is rectangular, 0.86 m wide and 1.94 m long on its interior, its walls rising 0.65 m high. We roofed the chamber with a barrel vault, adding at its maximum another 0.42 m to the height of the chamber. A tall, narrow chimney at the back could control the draft. We inserted a thermocouple midway in the roof of the chamber, and there were two spy holes at the sides. The entire chamber was constructed with refractory bricks, but we added a second layer on the exterior of less expensive aerated bricks, then coated the vault with a lime cement. We installed steel bars united by rods on the outer corners of the kiln to counteract the lateral thrust generated by the heating and expansion of the walls of the chamber. The bag wall in the interior could be constructed from refractory bricks after the wares were loaded in the back (Figure 6.24). Once loaded, the front of the kiln must be bricked up with the exception of narrow openings for adding fuel at

the base and above the midpoint of the wall. We allowed the mortar in the vault to cure for several weeks before firing.

Altogether the single chamber had a capacity of 1.65 m^3 . Leaving a minimum space for the fire and the bag wall, the length of the firing chamber is reduced to 1.19 m for a capacity of only 1.01 m^3 . For smaller loads, the front wall and the bag wall could have been erected further back to reduce the total firing space.

6.F.3) *Firing process*

We loaded the kiln with a charge weighing approximately 490 kg before firing. We loaded two replica tiles, more than 200 hundred test bricks, and a few small figurines. For two people, this took less than 45 minutes. Several test bricks which we had laid horizontally cracked because they were excessively loaded, emphasizing to us the importance of standing bricks and tiles on end to prevent shearing. We installed the bag wall and built the temporary front wall from refractory bricks, filling the seams with clay. Having ordered approximately 1,600 kg of branches pruned from a variety of fruit trees for delivery, two of us transferred the wood 25 m to the side of the kiln using a wheelbarrow in 80 minutes.

We fired the kiln from 7 pm on August 1st, 2006 through 9 pm the following evening. Lighting a small fire at the base of the front door, we held the temperature below 100°C for 14 hours. We burned brush and paper as kindling, switching to small branches once the fire picked up and the draft was established. This pre-firing drove away moisture remaining in the pores of the ceramics and further dried the mortared joints in the vaulted ceiling of the kiln.

The next morning, for 4.5 hours from 9 am to 1:30 pm, we gradually raised the temperature to 300°C . The firing temperature and the total amount of wood fed into the kiln are plotted in Figure 6.25. After holding the temperature just above 100°C

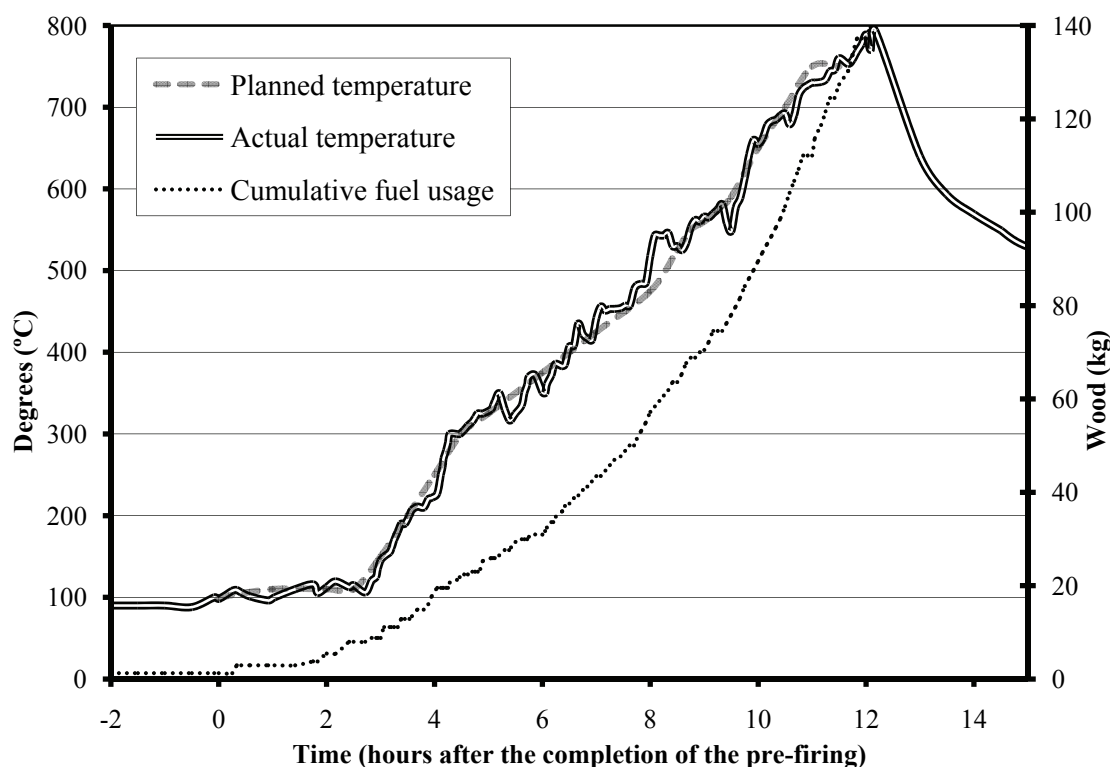


Figure 6.25 Readings from the thermocouple during the experimental firing

until 11:30 am, we reduced the aperture of the lower portal and stoked the fire higher by adding several handfuls of small branches into the upper portal. At this time, the temperature rose very quickly as each branch caught fire. We added a few branches every 5 or 10 minutes, and only about 15 kg of wood was needed to reach 300 °C. We slowed the rate of heating between 300 and 600 °C, the temperatures at which excess carbon is driven from the fabric. Over the course of 5 hours from 1:30 to 6:30 pm, we added 59 kg of wood. We held the temperature for the last 30 minutes of this phase at around 573 °C, the temperature when the beta conversion of quartz places additional pressure on the clay body. For the final 2.5 hours, from 6:30 to 9 pm, we stoked the fire vigorously, adding about 2 kg of medium and large branches every 5 minutes. A final handful of wood at 9:05 pm drove the temperature to its peak at 794 °C, and the firing had completed (Figure 6.25). The kiln was soaked at about 750 °C, however, because only this temperature was consistently maintained for the hour between 8:20

and 9:20 pm. We sealed all the portals of the kiln and left it to cool gradually overnight. The temperature dropped steadily over the next 24 hours to 200 °C, when we opened the slots to accelerate the final cooling. With a reading of 46 °C, the chamber was opened at 1:45 pm the following day, 40.5 hours after reaching its maximum temperature. No objects had been damaged from the firing. In total, we had used only 140 kg of wood for a 12-hour firing.

The next day we unloaded the chamber. We cleaned soot from the two replica tiles in the batch and noticed their color and density had changed. The tiles and bricks emitted a slight ring when tapped, indicating that they had been adequately fired.

6.F.4) Post-firing modifications

10. All tiles are heavily retooled along the overlapping edges in order to create a tight joint with neighboring tiles.

Because all Protocorinthian tiles had been chiseled to fit one another on the roof, we tried to chisel the replica tiles. We set the tiles on their back ends to lean against a wall and cushioned the top side. We first cut a line into the bottom of the tile with the chisel, marking the inside edge of the pan rabbet. Without damaging the tile, it was possible to remove a depth of about 1 or 2 mm of material (Figure 6.26). By



Figure 6.26 Chiseling the pan rabbet



Figure 6.27 The fired full-scale replica tile

working over the area of the pan rabbet with many fast strikes in parallel rows, it was possible to cut the rabbet in a controlled and safe fashion. We also trimmed the free edge of the cover rabbet. Where the cover thinned to only 1.7 cm near its back, a small fragment was inadvertently dislodged from one tile, but otherwise the replicas were unharmed by chiseling. Cutting the pan rabbet and trimming the cover rabbet took 19 minutes, but with more experience this might have been reduced to about 10 minutes per tile.

6.G) Results

In the experiments of 2004 and 2006, we created five replicas of regular Protocorinthian tiles and three clay base molds in Corinth. Three of the tiles were finished successfully, of which two were fired and the other held in reserve. In all we produced 45 test bricks in standardized frames, 11 large and 34 small, and about 180 other tiles to load the kiln.

6.G.1) Protocorinthian tile replicas

Although three of the five replicas were produced at full scale, only one of the two fired replica tiles was full sized. We had slightly underestimated the shrinkage rate, so the full-sized replica was about 1.5 cm smaller than an actual Protocorinthian tile (Figure 6.27). Before firing, the cover was 24.5 x 63 cm, the pan 40.9 x 63.7 cm. After firing, the cover became 24.6 x 63.3 cm, the pan 41.2 x 63.9 cm. Its dimensions had enlarged by about 0.5%, a phenomenon also observed in the test bricks. The tile lightened from 28.1 to 26.8 kg during the firing, a 4.6% weight loss.

The fabric resembles that of the ancient tiles but is not a perfect likeness. The Agios Antonios clay fired very pale brown (10YR 6-7/4) throughout, exhibiting no reddening toward its interior. Its color value is slightly lower than the normal reading

for a Protocorinthian tile. This may be attributed to the firing temperature or the clay source.³⁶⁵ The thermocouple on the roof of the kiln tends to give a high reading because the heat from the combustion chamber reaches it first. Consequently, the temperature may have been significantly lower where the tiles were stacked than the sustained reading of 750 °C at the thermocouple.

The Acrocorinth mudstones occupy only about 15% of the cross section, which is slightly less than most Protocorinthian tiles (Figure 6.28).³⁶⁶ Although 2- to 4-mm fragments predominate, some are as large as 6 mm, indicating that the temper for the ancient tiles had been more carefully sifted. Small voids are somewhat more common than in a typical Protocorinthian tile, as if the replica clay had not been adequately wedged and was too dry when pressed into the mold.³⁶⁷ Due to its lower temper content, the replica fabric does not appear as laminated as the ancient tiles. These differences are minor, and we could have eliminated them by adding more temper, using a finer mesh to sieve mudstone, and treading the replica paste to eliminate more of the air pockets.

The surface features of the replica indicate that the hypothetical forming and finishing sequence is close to the ancient procedure. The slip had a brush-like quality, and the bottom edges along the front faces had been nicked while the tile was moved around the workplace, both features characteristic of the originals (Figure 6.29). The cuttings on the unslipped back edges, the notch, and the corner bevels closely resemble their ancient counterparts, although the markings on the back faces of some Protocorinthian tiles suggest the clay had been slightly wetter when it was

³⁶⁵ Perhaps some excess carbon remains in the fabric: Rice 1987, p. 343.

³⁶⁶ The 15% tempering material was due to an overestimation of the shrinkage of the Agios Antonios clay before it was mixed. Other clays mixed for bricks with 25-30% temper closely resembled the ancient tiles in cross section.

³⁶⁷ This might have been circumvented by treading or hand wedging. Traditional foot treading is most effective when a large quantity of paste is prepared at one time, although we never worked at so large a scale.

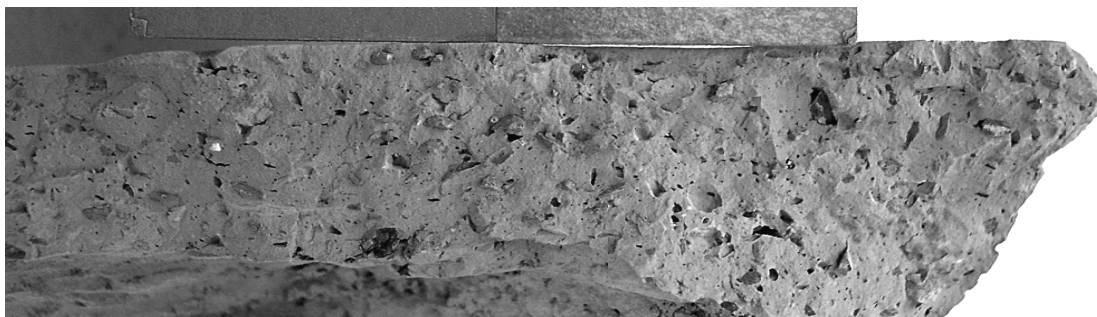


Figure 6.28 Replica: view of break (*scale card at top is 6 cm wide*)

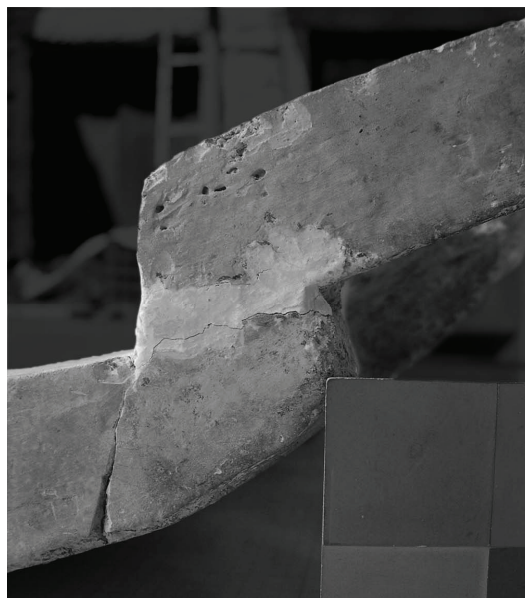


Figure 6.29 Cover-pan joint on the front: (*left*) replica and (*right*) FP 110

Figure 6.30 Back face and notch: (*left*) replica and (*right*) FC 62



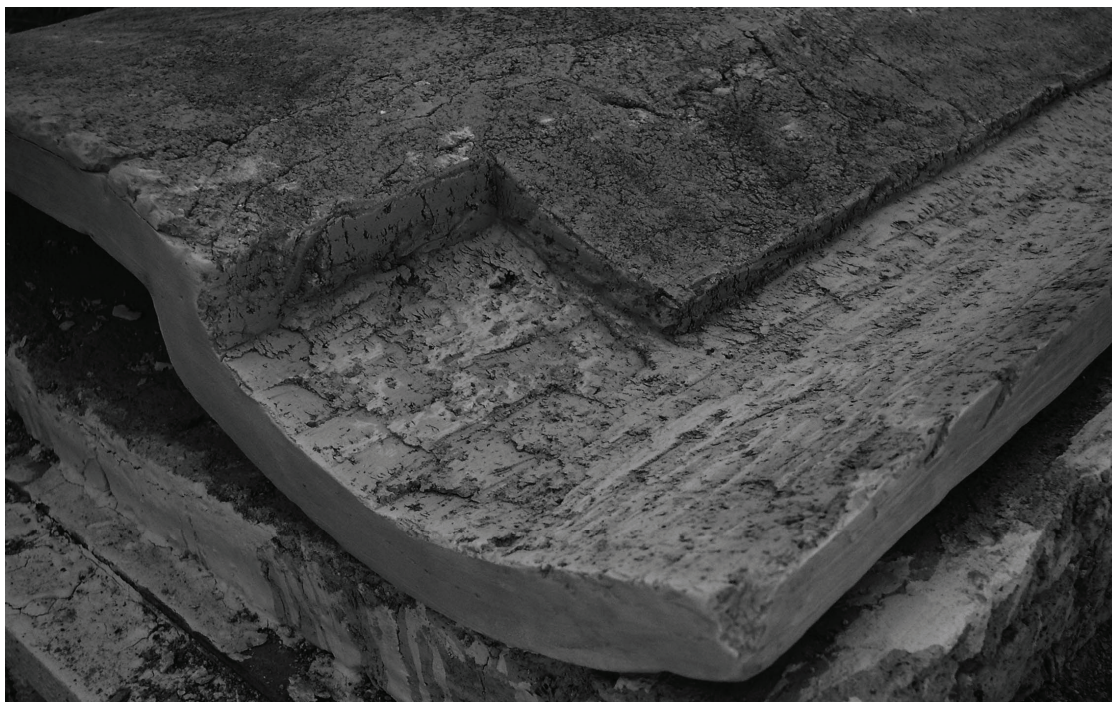
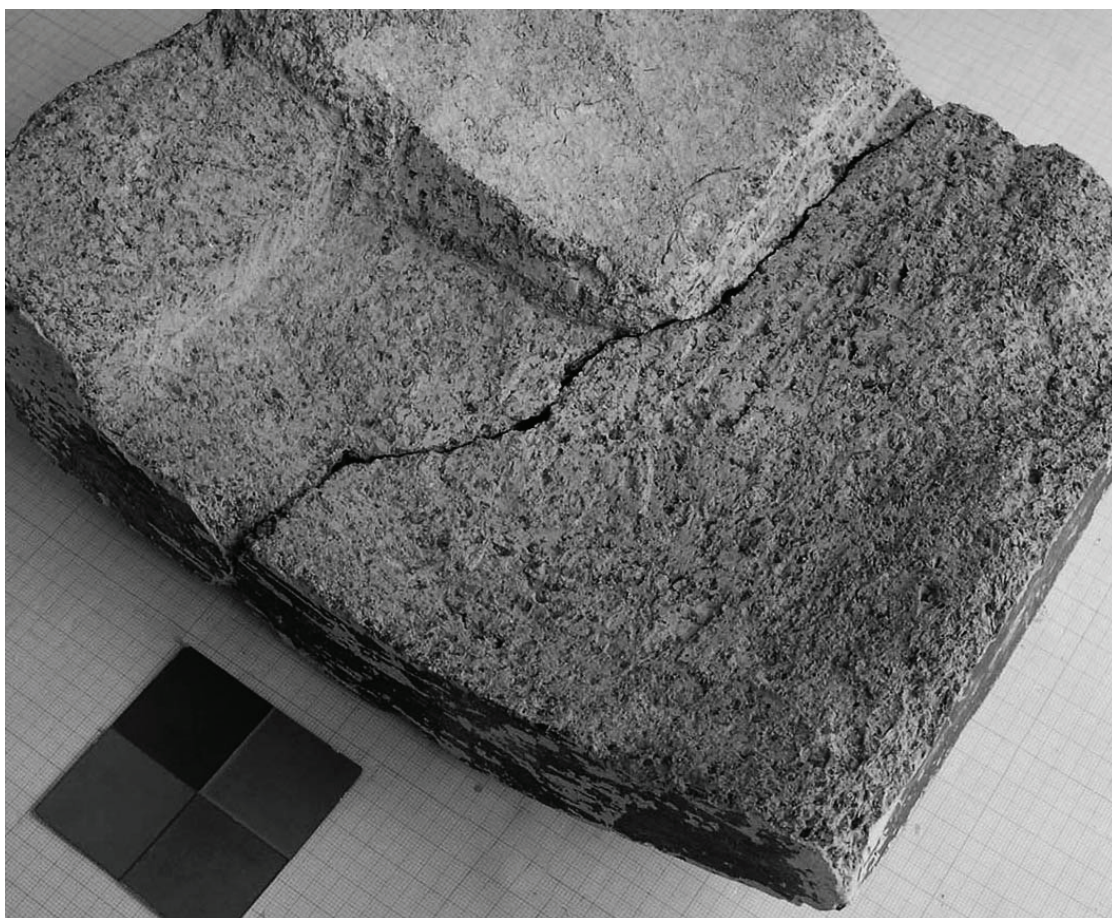


Figure 6.31 Cover rabbet: (*above*) replica and (*below*) FP 325



initially packed into the frame (Figure 6.30). On the underside, the separator layer of mudstone chips is an excellent likeness to the ancient tiles, as is the spatula-cut surface of the cover rabbet (Figure 6.31). The chiseling on the pan rabbet is also similar, although the ancient chiseling generally appears more haphazard.

The replica tiles fail to exhibit the transverse convex bowing typical in the originals.³⁶⁸ Instead, the replica pan is relatively flat, while the free end of the cover has a slight concave curvature. Because the convex bowing does not form spontaneously on the replica tile, it is more likely that the ancient striking procedure was responsible for the bowing rather than shrinkage distortions. In any case, the experiments do not provide a clear explanation for the phenomenon.

The second replica fired in the kiln is a scale model formed in Acrocorinth clay. Before firing, the cover was 24.0 x 52.9 cm, the pan 33.3 x 51.9 cm. After firing, the cover became 24.0 x 53.0 cm, the pan 33.4 x 52.1 cm. Its dimensions had enlarged by about 0.2%. The tile lightened from 27.2 to 25.7 kg during the firing, a 5.5% weight loss. The fabric fired to a uniform pink (7.5YR 7/4) on its surface, closer to reddish yellow (7.5YR 6/6) in its core where exposed by chiseling. In other regards, it is similar to the full-scale tile replica.

6.G.1) *Recipes for Corinthian clays*

We gained a wealth of practical knowledge from producing test bricks with Corinthian clays. First, we measured the amount of clay, water, and temper that went into each brick paste. After mixing several batches for each clay source, we developed recipes for the three principal clay sites (Table 6.1).³⁶⁹

³⁶⁸ See discussion above, Chapter 5.

³⁶⁹ i.e., nine batches of clays from the area of Ag. Demetrios, six from Ag. Antonios, and three from Acrocorinth. Three more from Aetopetra are excluded from the table because we prepared them differently.

Table 6.1 Recipes for 100 liters of clay with 0%, 20%, and 30% tempering

Site	Dry clay (<i>c</i>) + water (<i>w</i>) + temper (<i>t</i>), measured in L		
	no temper	20% temper	30% temper
Acrocorinth	120c + 60w + 0t	103c + 52w + 17t	95c + 48w + 25t
Ag. Antonios	130c + 54w + 0t	111c + 46w + 19t	102c + 43w + 28t
Ag. Demetrios	145c + 52w + 0t	128c + 46w + 17t	119c + 43w + 26t

The recipes are tailored to the requirements of fabricating tiles. The unconsolidated raw clays when they are mined have a low bulk density and shrink when wetted. The amount of water in the recipe is the minimum necessary for a soft paste that is easy to stir. However, this produces more than 100 liters of overly wet material. The clay was ready to pack into the mold at its optimum plasticity, when it had firmed and lost much of its stickiness yet was still completely malleable.³⁷⁰ We spread the clay on the patio and wedged it to develop this consistency, at which time the clay had contracted to 100 liters of optimal-plasticity paste weighing about 215 kg for all the clays.³⁷¹ The clay will experience more plastic drying shrinkage before becoming leather hard.

The recipes are very efficient compared to methods for preparing finer clay bodies in settling basins. In the replication experiments, the volumetric water/paste ratio is 0.5-0.6:1 depending on the site where it is mined. In a modern French studio producing replicas of Attic black gloss pottery, 10 liters of water and 2kg of dry clay produce 1kg of optimal-plasticity paste, equivalent to a water/paste ratio of 12.5:1.³⁷² Even if the ancient purification method had been more efficient, tile pastes require on the order of 10 times less water than the best fine wares.

As a nonplastic temper, the mudstone reduces the total amount of raw clay and water in 100 liters of paste by approximately 15-20%. The recipes compensate for the

³⁷⁰ Grim 1962, pp. 56-58, 57 table 3-1.

³⁷¹ From the bulk density of 2.15 kg/L, based on readings from 2.09 to 2.23 for six different batches of untempered clay. Also see Grim 1968, p. 467 and table 12-6, for moisture contents of similar clays based on density.

³⁷² Echallier and Montagu 1985, p. 142.

later drying shrinkage of the clays and will fire to a fabric containing 20% and 30% temper. The exact ratios of clay to temper in the table, such as 103:17 or 119:26, are unlikely to have been the ancient formulas and are calculated instead to produce an exact percentage of temper in the fired fabric. The ancient tile makers more likely would have measured out even parts of dry clay and mudstone, where the clay/mudstone ratio would be integers from 4:1 to 7:1 depending on the properties of the clay and the final quantity of tempering. Ancient ceramicists would not have carefully measured out water either, but they would have used ratios similar to those of the recipes in order to minimize the time for stirring and drying paste.

6.G.2) *Drying and shrinkage of test bricks*

The bricks stiffened rapidly after they had been shaped. Drying times are irregular due to the changing weather, but overall shrinkage measurements for the 45 test bricks are presented in Figure 6.32.

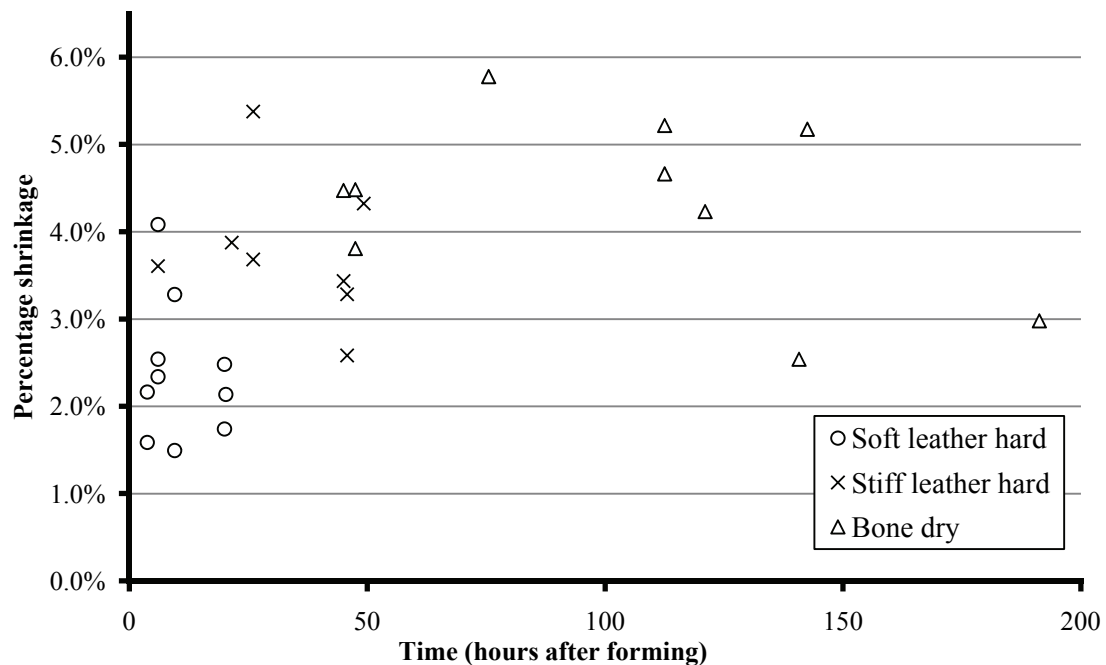


Figure 6.32 Shrinkage rates of test bricks from all clay sites

The measurement intervals were arbitrary, but they indicate that all bricks could be moved within 4 to 22 hours, when they had dried leather hard. In the “soft” leather hard condition, the tiles still felt damp and could be trimmed easily, similar to the replica tiles when we lifted them from the base mold to cut the cover rabbet on the underside. We moved the bricks to an enclosed space after they had become leather hard. They continued to dry and shrink rapidly until they reached the “stiff” leather hard state within 50 hours. At that point, the bricks are hard and resilient, not readily softening even when water is added, and cutting into the body is very difficult. There is little further shrinkage before the bricks become bone dry, which is marked primarily by a distinctive lightening in value that moves from the exposed edges of the piece to its interior. Although more than 200 hours passed before all the bricks became bone dry, the process might have been accelerated in a ventilated drying area. We tried leaving a few new bricks in direct sunlight. They could be moved in as little as 1 or 2 hours and approached the stiff leather-hard state within 6 hours.³⁷³ Perhaps 3 to 5 days would have been sufficient for Protocorinthian tiles to dry in a shaded area during favorable weather.

None of the bricks developed the convex transverse bowing observed on most ancient tiles (below, Figure 9.11). Out of 45 bricks, the majority were flat, but 14 of the small bricks were slightly concave on top. The concavity seems to be caused when the frames were pulled away, slightly lifting the edges of some bricks, and thus is not related to the rising toward the midpoint on the Protocorinthian tiles. Thus, as in the case of the replica tiles, the bricks supply no evidence that convex bowing on ancient tiles would have arisen from drying. Because the bricks are formed in a flat frame and are much easier to strike than the complex profile of the ancient tiles, it is more likely that the Protocorinthian tile frames are responsible for the bowing.

³⁷³ These points are omitted from Figure 6.32 for consistency.

We fired 36 of the bricks in the kiln, holding 9 in reserve. Because several bricks were damaged while we were loading the kiln and measuring the bricks, only 30 are presented in the statistical table (Table 6.2). The bricks shrank on average 3.5% to 6.1% from the optimum plastic to bone-dry state (dLS). After firing, the majority slightly expanded (FS). The average linear expansion relative to the bone-dry dimensions is 0.1%, but it varies from 0.3% for the Aetopetra bricks to zero net change for the Acrocorinth clay. The firing had reduced the weight by 5.0% to 7.2%, leaving the bricks at an average bulk density of 1.74 kg/L. The density is the same as the approximate average of 1.74 kg/L for four ancient tiles.³⁷⁴ As with the replica tiles, the bricks' colors range from reddish yellow (5YR 6/6) to very pale brown (10YR 7/4), slightly lower in value than the firing color of many Protocorinthian tiles.

The modest linear expansion during firing is a remarkable feature of these clays. Although firing usually shrinks ceramics, at temperatures up to about 800 °C the clay is subjected to net-expansive forces.³⁷⁵ The expansion is most prominent in smectite and illite clay minerals, which predominate in the Corinthia.³⁷⁶ During

Table 6.2 Linear shrinkage and weight loss for test bricks

Clay Site	dLS%	tLS%	WL%	FS%	dD	fD (kg/L)	Color
Acrocorinth	6.1 [7]	6.1 [5]	6.1 [5]	0.0 [5]	1.29	1.72 [2]	7.5YR 6-7/4
Aetopetra	5.2 [7]	4.9 [4]	7.2 [4]	-0.3 [4]	n/r	1.76 [1]	7.5YR 6-7/4
Ag. Antonios	3.5 [13]	3.4 [8]	5.3 [8]	-0.2 [8]	1.24	1.71 [3]	10YR 6-7/4
Ag. Demetrios	4.9 [18]	4.8 [13]	5.0 [13]	-0.1 [13]	1.12	1.77 [4]	5-7.5YR 6/6

[each numerical average is followed by the number of readings in brackets]

dLS = Linear shrinkage before firing

FS = Firing shrinkage

tLS = Total shrinkage after firing

dD = Dry bulk density (raw mined clay)

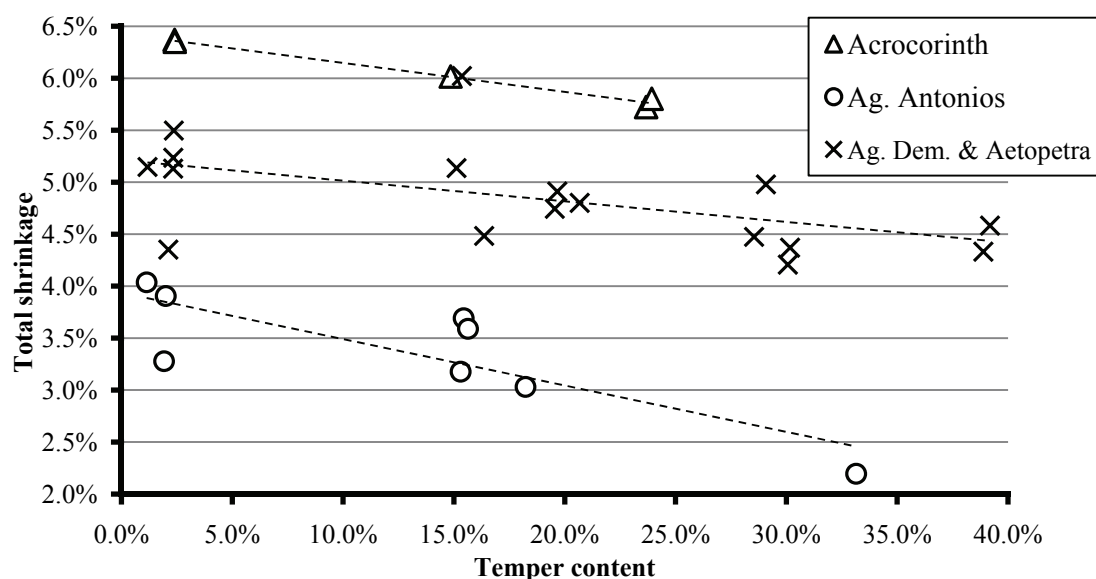
WL = Weight loss (from firing only)

fD = Fired bulk density (untempered)

³⁷⁴ i.e., FC 79 (1.86 kg/L), FR 104 (1.71 kg/L), FP 333 (1.77 kg/L), FP 343 (1.61 kg/L). A bulk density in the range of 1.4 to 2.2 kg/L is typical for manufactured tiles and building bricks despite a much higher specific gravity of 2.5-3.1 for the constituent clay minerals: Grim 1968, pp. 466-468; Grimshaw 1971, pp. 822-825, 820 table 12-17.

³⁷⁵ Cardew 2002, pp. 80-83; Matson 1971, p. 72; Rye 1976, pp. 110-112, 110 fig. 1.

³⁷⁶ Whitbread 2003, pp. 7-8. Also see: Rostoker and Gebhard 1981, pp. 226-227; Whitbread 1995, pp. 316, 326-327, 336; Vandiver and Koehler 1986, pp 210-211.



(*Ag. Demetrios and Aetopetra* clays have indistinguishable fired shrinkage rates)

Figure 6.33 Linear shrinkage plotted by tempering³⁷⁷

heating, smectites expand rapidly at 700-800 °C by about 1%, reversing to drop in volume only at higher temperatures.³⁷⁸ Illites expand more gradually by approximately 1 % from 450 to 800 °C and then retract to their original size by 900 to 950 °C.³⁷⁹ Heating expansion is reversible, but some permanent expansion may be caused by non-clay inclusions such as quartz inversion at 573 °C and the release of other gases while the clay body is hardening.³⁸⁰ An irreversible expansion of 0.2% is typical with relatively pure clay bodies fired to about 750 °C. Sand- or shell-tempered clays can resist permanent shrinkage as high as 1,000 °C.³⁸¹ In fact, omitting an outlier that shrank 0.5%, the 9 bricks with tempering greater than 20% expanded by 0.25%, which is significantly higher than the 0.11% average expansion for the 13 untempered bricks.

The addition of 2-4 mm particles of mudstone as tempering has a significant effect on total shrinkage (Figure 6.33). The effect is most pronounced for the Agios

³⁷⁷ The correlation coefficients for the fitted lines are -0.995, -0.829, and -0.534 for the Acrocorinth, Ag. Antonios, and Aetopetra/Ag. Demetrios clays, respectively.

³⁷⁸ Grim 1968, p. 327.

³⁷⁹ Grim 1962, pp. 117, 114 figure 3-24; 1968, pp. 338, 307 figure 9-20 (D,E).

³⁸⁰ Grim 1962, p. 120; Grimshaw 1971, pp. 798-799.

³⁸¹ Grimshaw 1971, pp. 799 figure 12.8, 805 table 12-12; Klemptner and Johnson 1986, pp. 260-261.

Table 6.3 Linear shrinkage for untempered and heavily tempered bricks

Clay Site	Linear shrinkage (%)		Weight loss (%)	
	>20% temper	no temper	>20% temper	no temper
Acrocorinth	5.8 [2]	6.3 [2]	6.4 [2]	5.7 [2]
Aetopetra	4.8 [3]	5.1 [1]	7.9 [3]	4.6 [1]
Ag. Antonios	2.2 [1]	3.7 [3]	6.0 [1]	3.6 [3]
Ag. Demetrios	4.5 [4]	5.1 [4]	4.7 [4]	4.9 [4]

[each numerical average is followed by the number of readings in brackets]

Antonios clays. The already low average shrinkage of 3.7% drops to 2.2% net shrinkage with the addition of 33% tempering, and the effect is repeated to a lesser extent for the other clays (Table 6.3). The amount of tempering also correlates to weight loss, although it is unclear why adding more nonplastics to the paste would increase the total weight loss from firing.

To conclude, with about 25% nonplastic inclusions added to the clay, the fabric of Protocorinthian tiles is optimized to reduce linear shrinkage while preserving strength.³⁸² Because the bulk density of mudstone is about 1.25 kg/L, its use as a temper may lighten the fabric slightly. Although its performance characteristics remained untested, mudstone temper may also have improved impact and thermal shock resistance.³⁸³ Its presence may have extended the resistance of smectites and illites to irreversible firing shrinkage at 750 to 800 °C. It is possible that Protocorinthian tiles were fired as high as 900 °C without appreciable shrinkage from the bone-dry state.

Overall, the temperature in the experimental kiln appears to have been sufficient for firing the clays but lower than ideal for Protocorinthian tiles. The fired replica tiles were strong enough to survive chiseling, and the bricks emitted a ring when tapped. After unloading the kiln, we tried docking 10 bricks from each of the four sites. When placed in the water basin, the bricks vigorously released air bubbles

³⁸² Grim 1962, p. 77; Grimshaw 1971, p. 550.

³⁸³ e.g., Bronitsky and Hamer 1986.

and some heat, probably from the formation of calcium hydroxide from decomposed calcium oxides in the fabric.³⁸⁴ After the bubbling ceased, we measured the apparent porosity of the Agios Demetrios clays at 25%, and the other sites ranged from 28-38%. However, two bricks disintegrated and three more cracked, representing each of the clay sources, so the experimental docking was unsuccessful. After one year, the remaining docked and undocked bricks both had survived in a sheltered space, but a fraction of other small tiles left outdoors had disintegrated. Both smectites and illites have been almost completely freed of their adsorbed water after firing to 450 to 650/700 °C, so the clays should have been decomposed during the experimental firing. The crystalline structure of the clays persists until higher temperatures, although sintering may solidify the matrix before any glassy phases form at higher temperatures.³⁸⁵ Further experiments are necessary, but it appears that to achieve a weatherproof ceramic body Corinthian clays must be fired at 800 °C or higher.

6.G.3) *Materials and labor for fabricating a Protocorinthian tile*

It is possible to estimate the quantity of paste in regular Protocorinthian tiles by means of computer models. First, the standard cover-pan profiles are generated by blending sections from many ancient fragments. Next, the overall dimensions of the model are set to the average for all tile fragments, which is 67.1 x 65.0 x 4.1 cm (maximum length, transverse dimension, pan thickness). Finally, a model is generated for every production step when paste is added or removed from the tile. The computer is able to calculate precisely the volume of each component of the tile model. For every production step, the table below presents the fired volume of the tile model and

³⁸⁴ The heat of wetting for smectite and illite clays is unlikely to account for this effect: Grim 1968, p. 270-273, 275.

³⁸⁵ Cardew 2002, pp. 80-81; Grim 1962, pp. 90, 106; 1968, pp. 315, 318, 332-325.

the corresponding quantity of optimal-plasticity paste before drying shrinkage occurs (Table 6.4).

A total shrinkage of 4.2% has been calculated as typical for the Aetopetra and Agios Antonios clays, which we prefer over the other two sources. We averaged the total pre-firing shrinkage of test bricks from the two sites with more than 20% temper.³⁸⁶ We assume no net firing expansion because Protocorinthian tiles would have been fired slightly hotter than the experimental kiln. Consequently, each regular combination tile requires close to 23.0 liters of optimal-plasticity paste, from which 2.0 liters is cut away and recycled for other tiles. The equivalent of 0.5 liters of optimal-plasticity paste is chiseled from the tile after firing and cannot be used elsewhere. Thus, an average tile contains 17.9 liters of fired fabric and requires 20.9 liters of optimal-plasticity paste. Small quantities are wasted during the forming process, however, so even an efficient routine would probably use closer to 21.0-21.2 liters per tile.

Table 6.4 Fired and optimal-plasticity paste volume in a regular tile

Basis of an average tile experiencing 4.2% total shrinkage

Production step	Fired volume (L)	Optimal paste (L)
Mold primary tile	+20.23	+23.01
Trim pan and cover	-0.56	-0.64
Cut notch	-0.11	-0.13
Cut corner bevels	-0.34	-0.39
Cut cover rabbet	-0.87	-0.99 [†]
Chisel cover rabbet	-0.12	discard
Chisel pan rabbet	-0.32	discard
Total fired clay	17.91	20.37
Total discarded clay	0.44	0.5

[†]At the time when the cover rabbet is cut, the tile has shrunk 2.1% from the primary forming size. However, the leather hard paste can be recycled by wetting until it expands back to optimal plasticity.

³⁸⁶ The 4.2% shrinkage is an average of 5 readings from the two sites.

In addition, every tile is slipped over exactly 0.5 m^2 of the fired surface. Assuming an average thickness of 0.5 mm and compensating for shrinkage, slightly less than 0.3 liters of pale slip would have been applied to every tile. An even smaller quantity of dark paint is necessary for the fifth of the tiles painted black.

These estimates are based on an averaged model. In reality, there is substantial variation among the regular Protocorinthian tiles. Thickness is the most significant. The thickness at the midpoint of the pan in the ancient fragments varies from 3.7 to 4.5 cm, which is approximately equivalent to a volume of optimal-plasticity paste of 21 to 25 liters per tile, rather than the simple average of 23 liters. Changes in thickness contribute the most variation to the overall size of the tile. Moreover, although cutting them removes less material, the rabbets are highly irregular because they are cut and chiseled freehand.

In conclusion, over the whole production of the roof, the average requirement for one regular tile is 21.0 liters of tempered paste and 0.3 liters of untempered, refined slip. For the Agios Antonios clay, the recipe is 22.7 liters dry clay, 4.6 liters mudstone, and 9.5 liters water for a fired tile with 25% tempering. For the slip, 0.4 liters of sieved dry clay mixed with 0.3 liters water is sufficient to develop a fine fraction of 0.3 liters. Although the fraction of clay in the dark paint is comparatively small, it requires significantly more water, perhaps about 3 liters per black tile.

6.G.4) *Equipment list*

Only a few tools are needed at the worksite. Besides a supply of lumber and woodworking tools such as chisels and hammers for constructing tile-making frames, we used several small basins to measure or store small quantities of clay. We broke up clays and mudstone with a stone pestle and a sledgehammer. We sifted clay and mudstone through several grades of wire meshes. In antiquity, similar meshes could

have been formed from perishable materials such as woven reeds or punched leather.³⁸⁷ We used a straight-edged board as a strike. We had two metal spatulas of different widths and a knife for smoothing and cutting the tiles after they had been formed.

The moveable set of tools and non-paste materials for making tiles is as follows:

- (a) Pestle for pounding clay
- (b) Fine and coarse sieves
- (c) Wood strike
- (d) Metal knife for trimming the sides and cutting the notch
- (e) Metal spatula for carving the underside rabbets, the corner bevels, and the setting lines
- (f) Chisel and hammer
- (g) Templates for the top and bottom profiles of the tiles
- (h) Ruler marked with important pre-firing dimensions
- (i) Basins for measuring out paste recipes
- (j) Top base mold: Two wood boards for the front and back profiles of the tile, and two more attached to the ends of the templates for stability and retaining the sides of the tile
- (k) Base mold: Four boards arranged similar to the tile-making frame

Only the knife and spatula are metal. The metal knife might have been replaced with a narrow strip of wood. However, because it is used to cut the rabbets when the clay is relatively resistant, the spatula would not have worked effectively unless made of metal.

The tile makers would have a reference profile for cutting the top and bottom curves of the tile into the wood profile templates for the base mold. The reference profile might have been a drawing or just a pair of top and bottom profile templates. A dowel marked to compensate for shrinkage at the full transverse dimension (65/67.8

³⁸⁷ Woven or leather sieves have been documented in many ethnographic studies of potters, e.g.: Combès and Louis 1967, pp. 47-48 (Tunisia); Hampe and Winter 1965, p. 5 (Italy); Rye and Evans 1976, p. 119 (Pakistan); Saraswati and Behura 1966, p. 28 (India).

cm), the lateral and rear overlaps (9/9.4 cm), and the notch length (4/4.2 cm) would have sufficed as a ruler.

6.G.5) Time to produce one tile

During the replication experiments, we recorded the times for each production step. The total labor invested in mixing paste for tiles is presented in the following table for a single worker (Table 6.5). The “ideal” value is our judgment of the time to perform a step in an efficient, large-scale ancient production environment, whereas “tested” is the actual timing from the experiments.

For one person working alone, enough tempered paste and slip can be prepared for a tile in as little as 35 minutes using the experimental procedure, although 75

Table 6.5 Individual time cost (minutes) for paste preparation per tile

[necessary waiting periods between steps are in brackets]

Production step	Ideal	Tested	Notes
Paste preparation			
Mine dry clay (23.1 L)	5-8	8-15	Faster in an established quarry
Mine temper (4.6 L)	1	1	
Sieve temper (4.6 L)	3-5	3-10	Slowed by reprocessing pounded temper
Mining subtotal	9-14	12-26	
Beat clay	3-5	4-16	Slow in early tests
Beat temper	-	5	Omit: sieve at mine site
Measure recipes	2	2-5	
Add water and stir paste	2-3	2-15	Additional stirring unnecessary
Sieve and stir slip (0.4 L)	1	1	Fast preparation in larger batches
Mixing subtotal	8-11	14-42	
Leave paste to settle	[20-60]	[5-31]	Longer settling times save labor stirring
Spread out to dry	2-5	2-7	
Leave to harden	[20-60]	[20-80]	Depends on weather conditions
Wedge slabs (20-40 drops)	15-30	8-38	Replica tile fabric inadequately wedged
Decant slip	1	1-3	
Total labor	35-61	37-116	
Labor at worksite	26-47	25-90	Excluding mining time
Total waiting	[40-120]	[25-111]	

minutes total are necessary to allow time for drying the paste. This does not include transportation times which were not simulated experimentally. Some steps are more strenuous than others. Mining clay with a pick, sieving temper, and wedging probably could not be performed by one worker continuously throughout a work day, but these activities are interspersed with lighter tasks and natural pauses in the routine. Nevertheless, the most strenuous tasks do not exceed the modern industrial classification of heavy labor, which can be sustained by an average worker for as long as 4 hours every day.³⁸⁸

The most time-consuming step is wedging. Although we wedged some batches of paste relatively quickly, they appeared inadequately kneaded in the visible break seams after firing. However, foot treading may have been more efficient. We wedged by hand in the experiments because we produced less than 50 liters of paste at a time.

Table 6.6 Individual time cost (minutes) for forming one tile
[necessary waiting periods between steps are in brackets]

Production step	Ideal	Tested	Notes
Fit templates around base	1	1	
Pack clay into mold	8-12	10-24	Some tests inefficient
Strike top	7-10	10-25	Speed increases with skill
Cut sides loose	1	1	
Remove templates	1	1	
Trim free edges of tile	1-2	1-2	
Cut notch	1	1	
Apply and polish slip	5-7	5-19	Some tests slowed by impure slip
Cut corner bevels	1-2	1-2	
Soft forming subtotal	26-37	31-76	
Dry leather hard	<i>[360-1440]</i>	<i>[1060-2200]</i>	Depends on weather conditions
Lift tile	2-3	2-3	Time for two workers cooperating
Cut cover rabbet	4-10	4-17	Depends on resistance of clay
Incise setting lines	1-2	-	Not replicated
Move to drying area	1-2	2	
Total labor	34-54	39-98	

³⁸⁸ See Consolazio, Johnson, and Pecora 1963, p. 358 table 9.7; Durnin and Passmore 1967, pp. 47-73, especially 62-64.

The time for an individual laborer to shape a tile is presented in Table 6.6. One person alone could have formed the tile while it remained on the base mold. Many activities are suited to working with an assistant. Two workers can pack clay into the mold, rub slip over the surface of a tile, or cut the free edges and corner bevels without getting in each other's way, doubling the production speed. A craftsman skilled with the strike could work faster with an assistant patching seams and polishing grooves. Thus, in an intensive production, two workers together might shape a tile in about 15 minutes before leaving it to dry. After the tile dried soft leather hard, two workers would have lifted it together to access the underside and to move it to the drying area. The cover rabbet is large enough also to be trimmed by two workers together. In conclusion, the forming and finishing sequence for one tile excluding clay preparation and firing is less than 25 minutes for two workers.

CHAPTER 7: ORGANIZATION AND SCALE OF CORINTHIAN POTTERY AND TILE PRODUCTION

Although the general model for tile making developed in Chapter 4 illuminates many technical aspects of tile production, it cannot be directly applied to Protocorinthian tiles. Corinth in the early seventh century B.C. had no equivalent to a tile or brick industry. Most Corinthian architecture at the time was unfired mud brick, and tiles were not yet known. To produce the roof of the Old Temple, the Corinthians cannot have relied on an established tradition of tile making. In the Greek world, tiles were reserved for monumental sacred architecture through the sixth century. Even if roofs had been produced for earlier Greek temples, an economic comparison to the recent tradition of making tiles for domestic architecture is problematic. Only Etruscan settlements developed the techniques for mass producing plain cover and pan tiles for domestic architecture by the middle or at least the third quarter of the seventh century B.C.³⁸⁹ Moreover, the Protocorinthian roofing system was an anomalous prototype which was used only for a few exceptionally large early cult buildings. The individual tiles were much heavier and more complex than plain modern covers, and each tile required more production steps and a higher investment of labor.

Consequently, an alternative model is necessary in order to determine which elements of traditional Mediterranean modes of tile and brick production are appropriate for comparison to Protocorinthian tiles. We may assume that the full array of skills and knowledge possessed by contemporary potters would have been applied to the new problem of tile production. By turning instead to the blossoming pottery industry of seventh-century Corinth, it is possible to model the competence of the

³⁸⁹ Poggio Civitate (Murlo): Berkin 2003, pp. 25-26, 116-118; Nielsen 1987; Nielsen and Phillips 1985, p. 69; Nielsen and Tuck 2001. Acquarossa: Ö. Wikander 1990; 1992, pp. 157-161. At Acquarossa, over a million tiles were produced over a century of occupation, equivalent to an average annual production of roughly 11,000 tiles of all types: Ö. Wikander 1993, pp. 137-139.

Corinthian potters. Two interrelated lines of analysis are helpful for assessing the skill base of these early Archaic craftsmen: the organization of pottery production, and the degree of producer specialization.

Potters and tile makers in antiquity appear generally to have been of relatively low social status, regardless of their degree of skill.³⁹⁰ Many potters would have been occupied only seasonally, while others perhaps were itinerant. The picture emerging from a synthesis of archaeological, epigraphic, and literary sources is that the most distinctive Archaic and Classical pottery was produced in small, independent workshops organized under a master potter with a small staff, almost always under ten workers.³⁹¹ We may begin with an assumption that by the opening of the seventh century B.C., Corinth—like many other pottery-producing Greek centers—had a pottery industry with specialist producers, meaning that certain skilled individuals obtained part or all of their income by producing pottery for consumption by others.

7.A) Ethnographic models of ancient pottery production

To some degree, the situation may be clarified by resorting to ethnographic comparisons, especially to the village potteries still active after the Second World War in the Mediterranean.³⁹² In order to target the most appropriate cases for drawing analogies to the archaeological record, classifications for the organization of production have been proposed by van der Leeuw and Costin, among others.³⁹³ Although developed for the Roman pottery industry, Peacock's classification is relevant because it is based on an intensive study of Mediterranean and European

³⁹⁰ Arafat and Morgan 1989, p. 312; Billot 2000, pp. 231-233; Crielaard 1999, p. 55; de Ste. Croix 1981, pp. 274-275; Noble 1988, pp. 12-14; Richter 1923, pp. 98-100; Vickers and Gill 1994, pp. 95-97.

³⁹¹ e.g., Scheibler 1983, pp. 110-112; Sparkes 1991, pp. 10-11; Stissi 1999, p. 87.

³⁹² A good overview is provided by Hampe and Winter 1962, 1965.

³⁹³ Costin 1991, pp. 3-18; van der Leeuw 1976, pp. 401-404; 1977, pp. 71-74.

ethnographic studies, corresponding to the ecological zones of the Roman empire.³⁹⁴ Expanding upon the models proposed by van der Leeuw, Peacock divides his modern and historically documented pottery centers into eight modes of production (Table 7.1). He developed certain modes to match his expectations for the Roman economy, and other descriptions of Northern Europe are outside the climate zone and raw materials available at Corinth. However, a few modes are directly comparable to the production environment for Protocorinthian tiles.

Relative to the problem of tile production at Corinth, Peacock's first two categories, household production and household industry, are inappropriate as analogies. These involve low-skill domestic production with little or no investment in equipment like kilns or turntables capable of high speed rotation. The pottery is plain and irregular, bearing little technical resemblance to Late Geometric or Archaic Greek black gloss wares.³⁹⁵ These may be eliminated immediately as potential analogues for the higher-quality products of the Corinthian industry. Moreover, Peacock's final two categories, estate production and official production, are tailored specifically for the

Table 7.1 Modes of pottery production in the Roman economy (Peacock 1982)

(Factory, Estate, and Military/Official Production are omitted)

Household production	Household makes pots for its own consumption; usually by women; no special equipment
Household industry	Family occasionally produces pottery for the local market; rudimentary equipment (perhaps turntable, oven)
Individual workshops	Pottery making a vital source of income, dominated by males and hired assistants; efficient routines, some investment (wheel, kiln)
Nucleated workshops	Cluster of many individual workshops arising due to favorable conditions; year-round production, standardization, major capital investment; middlemen for export market
Manufactory	Intensive; dozen or more craftsmen working in a highly specialized production sequence or in parallel (without mechanical power)

³⁹⁴ Peacock 1982, especially pp. 6-11.

³⁹⁵ Peacock 1982, pp. 8, 13-25.

Roman economy, and his sixth mode of factory production covers only machine-powered industry, also inappropriate for Greek pottery production.³⁹⁶

Peacock's remaining modes of production are individual workshops, nucleated workshops, and the manufactory,³⁹⁷ each of which include ethnographic cases that are useful models for Archaic Corinthian organization. Within these modes, potters derive vital or primary income from their products, and equipment investments can include wheels and kilns. Assistants outside the family of the potter are often employed, improving the efficiency of the production sequence, but no significant mechanization is involved. Production can continue throughout the year, but more often it is concentrated in the most advantageous seasons for potting.

These three levels form a continuum in terms of archaeological visibility, given the nuanced differentiations in Peacock's classification. Individual workshops are still based in the potter's home but also include some cases of itinerant production, where potters temporarily relocate near different markets. On the other hand, although potters may live at or nearby their workshops, the facilities for nucleated industries and manufactories are primarily commercial. These workshops cluster around advantageous resources and markets. Production is highly organized, with cooperation among craftsmen and assistants at varying levels of skill. The collaboration within workshops allows craftsmen to develop specializations within the production sequence. The wares are fired in large kilns and distributed by middlemen. For Peacock, the typical pottery manufactory developed only in late eighteenth-century Britain and is distinguished from nucleated industries by the size of individual workshops. Manufactories often employ more than twelve craftsmen, and in the case of pottery production, individual workers are assigned a highly specialized, repetitive

³⁹⁶ Peacock 1982, pp. 10-11, 46-50.

³⁹⁷ Peacock 1982, pp. 9-10, 25-46.

job within the production sequence. Capital investment in facilities is high. Peacock characterizes the large pottery industry at Nabeul, Tunisia, as a manufactory, although the features of pottery manufactories are often difficult to discern in the archaeological record.³⁹⁸ While some goods certainly were produced in manufactories during antiquity, it is questionable whether pottery ever reached this scale. Despite the enormous quantity of red gloss pottery distributed across the early Roman empire, only the few largest Arretine operations seem to have reached a scale equivalent to eighteenth-century manufactories.³⁹⁹ The majority of Gaulish workshops appear to have been relatively small and are characterized as “dispersed manufactories,” a scattering of small workshops coordinated by a central authority.⁴⁰⁰

With a common geography and climate, it is likely that individual workshops, nucleated workshops, or manufactories in ancient Corinth would have operated according to the production calendar of traditional potters in the Mediterranean basin. Although population concentrations, political boundaries, and economies have dramatically changed since antiquity, the climate conditions and raw materials are directly comparable to the ethnographic present. The typical season for commercial potters is seven months from spring to fall, when the weather is best for throwing and firing. Production for longer than nine months is uncommon. In winter, cool temperatures and humidity greatly slow the drying of pottery, and high winds and rainstorms are unpredictable threats to firing an outdoor kiln. Potters making small vessels in an enclosed workshop can continue to work at a reduced rate through winter, but many leave for part-time agricultural labor when wages are high. Brick and tile makers, who must work outdoors and are dependent on the sun for rapid drying,

³⁹⁸ Peacock 1982, pp. 45-46.

³⁹⁹ Peacock 1982, pp. 9, 121-122.

⁴⁰⁰ Peacock 1982, pp. 10, 123-128.

are particularly responsive to the climate cycle.⁴⁰¹ Consequently, the Mediterranean climate is favorable for developing pottery and tile production during summer among farming communities.⁴⁰²

Many ethnographies record seasonal production. The Greek makers of *pitharia* around Koroni worked from May to October, although the cycle varied among workshops.⁴⁰³ To avoid the rainy season, Cypriot potters typically are active seven months from April to November.⁴⁰⁴ In Spain, nucleated workshops at Salvatierra de los Barros are active from March to November, while at Bailén the season was shorter, from April to September or October.⁴⁰⁵ Over winter, production slowed at Bailén as workshop owners performed maintenance on their facilities, and other workers found temporary employment tending olives. At Deir el-Gharbi near Ballâs, Egyptian potters worked intensively from March to November, seeking odd jobs during the wet winter season when the clay mines were too dangerous to enter.⁴⁰⁶ Brick makers in Fes worked only five or six months between May and October, abandoning the sites for agricultural labor over the winter and spring.⁴⁰⁷ At Guellala on Djerba, the production of individual workshops varied. Some operated year round, but other potters tended olives during part of the year. Potting was substantially more profitable during the summer there, because potters made only a fraction of their daily wages and excess profits during the winter seasons.⁴⁰⁸ The only notable exception to this seasonal pattern was the *tinaja* production in Spain. These massive storage jars with capacities of thousands of liters were created over the winter months from October to May.

⁴⁰¹ Peacock 1979, pp. 6-7.

⁴⁰² Arnold 1985, pp. 61-98; Jones 1986, pp. 873-875; Matson 1995, pp. 1562-1564; Scheibler 1983, p. 118.

⁴⁰³ Blitzer 1990, p. 679.

⁴⁰⁴ London, Egoumenidou, and Karageorghis 1990, p. 52.

⁴⁰⁵ Salvatierra de los Barros: Vossen 1984, p. 344. Bailén: Curtis 1962, p. 488; Vossen 1984, p. 349.

⁴⁰⁶ Nicholson and Patterson 1985b, pp. 224-225, 236.

⁴⁰⁷ Bel 1918, pp. 41, 48.

⁴⁰⁸ Combès and Louis 1967, pp. 232, 269-271.

Because each jar had to be kept damp to prevent cracking while it was gradually constructed over eight or nine months, winter was a better time to work.⁴⁰⁹ During the high season, these potters worked long hours, often ten to fourteen hours a day for five or six days a week.

Determining where ancient Corinth fit into Peacock's classification of production is difficult. Scholars initially characterized the Corinthian pottery industry of the seventh and early sixth centuries B.C. as factory production, which invites comparison with Peacock's manufactory model. Until recently, the wide distribution of standardized seventh-century Corinthian wares in the Mediterranean was assumed to be the result of the "mass production" of pottery for export,⁴¹⁰ and the excavators of the Potters' Quarter at the west of the settlement uncritically interpreted the seventh-century buildings as pottery "factories."⁴¹¹

Arafat and Morgan, however, criticized this interpretation after reviewing the evidence for pottery production in Archaic Corinth. They suggest that the volume of pottery produced at Corinth on an annual basis may have been relatively low and that earlier descriptions of "mass production" were exaggerations based only on the distinctiveness of Archaic Corinthian exports.⁴¹² Moreover, several types of Corinthian pottery must have been produced elsewhere in the settlement, which contradicts the characterization of the Potter's Quarter as a single, centralized factory (below, Figure 7.16). Its architecture has been reinterpreted as primarily residential with less intensive pottery and terracotta production among the houses.⁴¹³ Following Peacock's classification, Arafat and Morgan argue instead that only individual

⁴⁰⁹ Garcia Fernández 1948, p. 655; also see below, note 584.

⁴¹⁰ Benson 1983, 1985; Salmon 1984, pp. 101-116, 159-164.

⁴¹¹ The late seventh-century South Long Building as a "factory": Stillwell 1948, pp. 17-18. On the possibility of earlier seventh-century factories: Stillwell 1948, p. 11-13.

⁴¹² Arafat and Morgan 1989, pp. 323-327, 338.

⁴¹³ Arafat and Morgan 1989, pp. 323-325; Benson 1984; Brownlee 2003, pp. 182-184; Williams 1981, pp. 418-419; 1982, pp. 17-18.

workshops and perhaps nucleated workshops had ever been active at Corinth.⁴¹⁴ In this picture, the site would have had spatially dispersed, family-run workshops, and the total number of potters active during any period would not have been very high.⁴¹⁵

7.B) Scale and organization of the Classical Athenian pottery industry

A comparison with Attic pottery provides insight into the organization of production at Corinth. Attic black gloss pottery is richly documented, and consequently it may serve as an intermediary for ethnographic analogies to Corinthian pottery production.⁴¹⁶ Beazley's stylistic classification of black-figure and red-figure painters provides an opportunity for a quantitative analysis of the scale of the entire industry.⁴¹⁷ Because the literary and epigraphic sources are virtually silent about the scale and organization of pottery production in the classical world, Athens represents one of the only opportunities to estimate the number of craftsmen and their total annual productivity. Such figures are invaluable when searching for ethnographic comparisons with pottery producers of an equivalent scale.

7.B.1) Athenian painters

Robert Cook was the first to use Beazley's classification of painters to estimate the number of craftsmen employed at one time during the fifth century B.C. in Athens.⁴¹⁸ Observing that the total number of red-figure painters and groups identified by Beazley is about 500, Cook suggested that if an average painter had a career of 25 years, then perhaps 125 or fewer individual painters were active at any given time

⁴¹⁴ Arafat and Morgan 1989, pp. 316-325.

⁴¹⁵ Arafat and Morgan 1989, pp. 336-338; Morgan 1995, pp. 318-332, 343-344. See also Crielaard 1999, p. 54.

⁴¹⁶ Arafat and Morgan 1989, p. 323.

⁴¹⁷ Beazley 1956, 1963. Also see Hannestad 1991; Oakley 1999.

⁴¹⁸ Cook 1959, pp. 119.

(more than 750 painters and groups are classified in the second edition of *Attic Red-Figure Vase-Painters* published a few years later).⁴¹⁹ Cook also derived the number of painters from the total number of extant red-figure vases, which he estimated at close to 40,000 vases and sherds produced over the 150 years of the industry's height.⁴²⁰ He then estimated the average annual rate of production per painter needed to produce this many sherds, which indicated that roughly 100 painters were active at once.⁴²¹ By assuming that every painter worked with three assistants, Cook estimated 400 craftsmen were employed during fifth century Athens. The lower numbers of sherds from the sixth century suggest only 200 craftsmen.⁴²²

An influential part of Cook's numerical study was his proposal of a method for estimating the total recovery rate for decorated Attic pottery. The recovery rate is the total number of attributed sherds known from museum collections divided by the total number of decorated pots produced in antiquity and expressed as a percentage. He calculated the recovery rate by dividing the number of Panathenaic prize amphoras in modern collections by an estimate for the total number of amphoras commissioned for every festival in the fifth century B.C.⁴²³ Many scholars interested in quantifying the

⁴¹⁹ Beazley 1963; Scheibler estimates 1000 painters of red figure over 150 years: Scheibler 1983, p. 113. See also Kurtz 1994.

⁴²⁰ Cook's estimate appears to be very accurate. A WWW search through the Beazley archive for "red-figure" resulted in 43,168 records. Of these, 35,282 are dated within 50-year periods. A total of 33,050 sherds date to 525-375 BC, the major period of production for red-figure pottery. By distributing the undated sherds proportionally, the corrected total is extrapolated to be 40,437 sherds in 150 years (or 94% of all red-figure pottery). Electronic database accessed Sept. 28, 2007: <http://www.beazley.ox.ac.uk/databases/pottery.htm>.

⁴²¹ He calculated that 3-4 sherds ended up in museums for each year of the career of a prolific painters such as the Berlin Painter. Regardless of the preservation rate, the 40,000 sherds in collections would take 10,000 to 13,000 "years" for a single painter to generate. Because the time span of production is only 150 years, then roughly 70 to 90 painters were active. As will be demonstrated below, Cook's calculation is flawed.

⁴²² Cook 1959, p. 121. The approximation of 500 potters is accepted by Snodgrass 1980, pp. 127-128 and Hannestad 1988, p. 223.

⁴²³ Cook 1959, p. 120. Cook assumes a constant 1,300 amphoras were made for every Panathenaia, meaning 32,500 were produced over the whole fifth century. The ninety preserved examples indicate a preservation rate of one sherd found for every five hundred produced according to Cook, or 0.28% as calculated in Oakley 1992, p. 199.

volume of Athenian trade have revisited this study. Different recovery rates have been proposed ranging from 0.2 to 10%, although others doubt the accuracy and general applicability of any of these ratios.⁴²⁴ Recently Bentz revised all the previous calculations in his book on these prize amphoras.⁴²⁵ In Bentz's comprehensive compilation, the recovery rates for Panathenaic amphoras over different phases of their production all fall between 0.9 and 1.6%. Bentz concludes that the average recovery rate of 1% already assumed in many studies of ancient Mediterranean trade is legitimate for most applications (Table 7.2).⁴²⁶ It is significant that authors who discuss the recovery rate, whether skeptically or not, argue that fewer prize amphoras might have been created than indicated by the limited epigraphic evidence, but not vice-versa. In other words, if *fewer* of the amphoras were actually produced than is generally suspected, then the actual recovery rate can only be *higher* than the estimates. The implication is that the total recovery rate for all attributed Attic black gloss may be even higher than 1%, if the calculations are to be believed at all.

Cook's estimate of 40,000 recovered red-figure sherds spanning 150 years can be refined to gain an idea of the size of the red-figure industry during the fifth century B.C., the height of its production. More than 34,000 pots or sherds are dated between 500 and 400 B.C.,⁴²⁷ which at the probable recovery rate of 1% translates into a production rate for the entire industry of about 35,000 pots per year.⁴²⁸ If Cook's

⁴²⁴ Arafat and Morgan 1989, pp. 326-327; Hannestad 1988, p. 223; Johnston 1987, pp. 125-126; Morris 2005, pp. 95-99; Oakley 1992, pp. 198-200.

⁴²⁵ Bentz 1998, p. 18 and note 62.

⁴²⁶ In fact, the recovery rate is between 0.9 and 1.3% from 525 to 325 BC, with a jump in the recovery rate only during the final quarter of the fourth century BC: Bentz 1998, pp. 17-18. The 1% rate generally has been favored in the past, e.g.: Webster 1972, p. 4.; Scheibler 1984, p. 133.

⁴²⁷ Using the Beazley archive WWW search, 28,036 sherds are dated in this range, although half of the sherd counts for 525-475 and 425-375 are included for this total. Because the sherd counts are generally higher within the fifth century than the quarter centuries preceding and following it, this figure may be slightly too low. Including the entire 43,168 records, we can extrapolate that 34,302 would have dated to the fifth century BC.

⁴²⁸ i.e., 34,302 recovered pots / 1% recovery = 3,430,200 total pots produced over 100 years. The 3.4 million pots / 100 years = 34,302 pots / year. Even if 1% slightly overestimates the recovery rate, the average production rate for the century is unlikely to have exceeded 35,000 pots / year. Bentz's restudy

Table 7.2 Numbers of prize amphoras from 566 to ca 300 B.C. (after Bentz 1998)

Period	Expected	Sherds found	Recovery rate
530-502 B.C.	12,156	120	0.99%
498-394 B.C.	41,027	373	0.91%
390-302 B.C.	34,949	450	1.29%
566-302 B.C.	100,287	995	0.99%

estimate of 100 painters being active simultaneously is accurate, an individual managed to decorate an average of only about 350 pots each year, which is little more than one or two red-figure pots a day. Apparently, a small team of craftsmen which included a potter, a painter, and assistants for acquiring raw materials and firing the wares would not decorate very many figured pots every year. However, there are several objections to Cook's methods for estimating the numbers of craftsmen who were simultaneously active, and his discussion of workshop organization is incomplete.

It must be assumed that the Athenian pottery workshops could have varied in size, perhaps from individual potters working largely alone up to highly organized shops.⁴²⁹ Some of the Athenian workshops may have been fairly successful financially, if several relatively expensive dedications on the Athenian acropolis are correctly attributed to potters.⁴³⁰ Assuming that all Panathenaic amphoras were produced in a single workshop, Valavanis argues that the Bakchios-Kittos workshop, which produced many prize amphoras in the mid-fourth century, employed more than 10 painters simultaneously.⁴³¹ Moreover, the large groupings of painters and potters

of all Panathenaic prize amphora sherds should be a reliable estimate of the overall recovery rate for the contemporary sherds: see above, note 426.

⁴²⁹ Arafat and Morgan 1989, 322-323; Scheibler 1984, pp. 131-132.

⁴³⁰ Beazley 1944, pp. 103-107; Richter 1923, pp. 100-105; Webster 1972, pp. 4-8, 295-300. The received list of potter dedications was recently dismissed by Vickers and Gill 1994, pp. 93-95.

Nevertheless, several dedications still are maintained to belong to potters: Johnston 2006, pp. 30-31.

⁴³¹ See below, note 522.

identified by Beazley, such as the Penthesilea Painter's group, have been cited as direct evidence for large workshops employing 10 to 20 painters at once.⁴³² However, the number of Beazley hands and the simultaneous employees in a workshop are not always clearly correlated. In a paper about the organization of sixth-century Attic production, Scheibler analyzes the interesting case of Nikosthenes, a relatively prolific potter who signed a relatively high proportion of his works (Figure 7.1).⁴³³ Nikosthenes also is associated with an unusually diverse group of painters, perhaps 35 to 40 hands in Beazley, which had been taken as meaning his workshop employed 30 or more painters simultaneously.⁴³⁴ Scheibler points out that many of the painters might not have worked all four decades that Nikosthenes was active. Furthermore, most of the painters were associated with only one extant vase, equivalent to only 100 total vases for their careers at the 1% recovery rate. Scheibler proposes an alternative scenario where only the most prolific painters collaborating with Nikosthenes were regular employees, which reduces the crew to two or three full-time painters. For Scheibler, most of the other hands would have been apprentices with other jobs or visiting painters, reducing the workshop to just six to eight people at any given time.⁴³⁵ This scenario has recently been supported by Tosto in his comprehensive study of Nikosthenic black figure.⁴³⁶ About 200 vases are attributed to Nikosthenes' group, and assuming the typical 1% recovery rate over his career, the per-painter output for a year is only 190 to 280 vases per painter with two or three painters working simultaneously—even lower than the production rate for red-figure potters calculated based on Cook's analysis.⁴³⁷

⁴³² Beazley 1944, pp. 111-112; Webster 1972, p. 41.

⁴³³ Roughly 200 vessels are attributed to Nikosthenes: Scheibler 1984, p. 132; Tosto 1999.

⁴³⁴ Eisman 1974, pp. 48-49; Immerwahr 1984, p. 345-347.

⁴³⁵ Scheibler 1984, pp. 132-134.

⁴³⁶ Tosto 1999, pp. 195-200.

⁴³⁷ i.e., 196 pots / 1% rec. = 19,600 pots over a 35 year career, or 560 pots / year. Nikosthenes' output was not steady over his career, so somewhat higher or lower annual production rates are possible as



Figure 7.1 Nikosthenic amphora, 31 cm high (Louvre F 111)



Figure 7.2 Kylix, Penthesilea Painter, 15.5 cm high (Boston MFA 03.815)

The Penthesilea Painter's group can be analyzed in a similar manner. This "workshop" is often pointed out as the best case for Athenian red-figure production at the manufactory level. Beazley gathers 22 distinct hands and groups in the workshop, which for about 30 years produced cups decorated with many small figures.⁴³⁸ The association of the painters within a single workshop is assured because two painters frequently decorate different sides of the same cup, which is very unusual for Athenian potters outside of this group (Figure 7.2). Its painters worked almost exclusively on smaller vases like cups and skyphoi, many designs are formulaic, and the draftsmanship often suffered from haste.⁴³⁹ The extreme variability in the number of attributions for Nikosthenes' painters is lacking with the Penthesileans, which

well: Tosto 1999, pp. 1-2, 14-15, 199-200. For similar estimates without showing the calculation: Scheibler 1983, p. 118.

⁴³⁸ Beazley 1963, pp. 877-971; 1971, pp. 428-435.

⁴³⁹ Beazley 1963, pp. 877-879; Robertson 1992, pp. 160-167. Scheibler, who argued the Nikosthenes workshop was far smaller than usually assumed, accepts the Penthesileans as perhaps the only case of an Attic pottery manufactory based on the many hands working within the workshop: Scheibler 1983, p. 116.

indicates many painters in the workshop were prolific. At the 1% recovery rate, the total of 1,558 vases translates to an average productivity of about 5,200 annually, about 260 pots per painter under the assumption that twenty worked simultaneously.⁴⁴⁰ Certain hands are clearly more prolific than others, ranging from the Painter of Bologna 417 with 223 attributed vases (almost all cups) down to the Group of Louvre C 11000 with only 2 attributed cups. In fact, the eleven most prolific painters decorated more than 80% of the vases attributed to the workshop.⁴⁴¹ Assuming the attribution rate corresponds to the relative productivity of an artisan, the Painter of Bologna 417 alone was responsible for 14% of the workshop's entire output. Working steadily over the whole lifetime of the workshop, he would have painted on average at least 730 cups a year,⁴⁴² which is twice the average rate deduced from Cook's estimation for red-figure pottery in general. If all the painters worked at about this speed, then no more than 7 painters would have been active at once, and a total of 5 or 6 full-time painters would be quite possible if each could decorate more than 1,000 of the hastily painted cups in a year.⁴⁴³ The other painters would have passed through the workshop in a shorter period, or else they would have worked at other tasks in the shop.

However, the individual productivity rates are not completely clear for the Penthesileans. There are ten minor hands, and many of the pots are not attributed to a specific painter at all, which makes the statistics difficult to interpret. Beazley's method for identifying hands is more successful for the better-known painters whose

⁴⁴⁰ i.e., 1558 pots / 1% rec. / 30 years = 5,193 pots / year (p-y). Then 5,193 p-y / 20 ptr. = 260 pots / ptr.

⁴⁴¹ The 11 most prolific painters, all of whom are attributed at least 65 vases each, painted 1247 of the 1558 pots.

⁴⁴² i.e., 220 pots / 1% rec. / 30 years = 733 p-y. Three cups were deducted from the total output for the Painter of Bologna 417 because he collaborated with other painters six times, decorating only half the cups.

⁴⁴³ i.e., 5,200 p-y / 5 ptr. = 1040 p-y / ptr. Assuming the Painter of Bologna 417 worked only 20 years full time rather than 35, he reached 1100 p-y.

personal styles are distinctive. The hundreds of minor hands to whom he attributes only a few vases are difficult data to interpret.⁴⁴⁴ A more reliable method for estimating the productivity of cup painters is to focus on a prolific individual instead. Douris is a good candidate because his attributions are corroborated by his signatures, which appear on more than fifty vases, all but two as the painter.⁴⁴⁵ His works were compiled in a recent monograph that gives him 248 certain and 35 more questionable attributions primarily in his 'Late' period, equivalent to 830 to 940 vases annually over a 30 year career at the 1% recovery rate.⁴⁴⁶ However, Douris worked with several different potters, and his 'Late' period was followed by a host of imitators, so it is difficult to draw any firm conclusions about the structure of the workshops where he painted.

The productivity of individual craftsmen within a complete workshop can be quantified more precisely in one of the best-studied groups of painters. The Berlin Painter was the first 'major' painter of this group, and his successors, the Achilles Painter and the Phiale Painter, were recently the subject of two detailed monographs by Oakley.⁴⁴⁷ The Berlin painter decorated about 780 to 840 vases annually over about 40 years (below, Figure 7.4).⁴⁴⁸ A later painter in the group, Hermonax, would have painted about 770 to 850 vases annually over about 25 years.⁴⁴⁹ In the second generation of the group, the Achilles Painter decorated about 770 to 990 vases

⁴⁴⁴ Kurtz 1994; Robertson 1985, pp. 25-28; 1992, pp. 4-6.

⁴⁴⁵ Buitron-Oliver 1995, pp. 1-3; Robertson 1992, 84-92.

⁴⁴⁶ i.e., 248 to 283 pots / 1% rec. / 30 years = 827 to 943 p-y: Beazley 1963, pp. 425-451; 1971, pp. 375-376; Buitron-Oliver 1995, pp. 72-88. Buitron-Oliver reduced the numbers from Beazley, who attributed 286 vases to Douris and 43 in his 'manner.'

⁴⁴⁷ Oakley 1990, 1997. These painters often have been viewed as a workshop: Robertson 1992, pp. 66-83, 193-210.

⁴⁴⁸ i.e., 311 to 337 pots (omitting and including 'manner') / 1% rec. / 40 years = 778 to 843 p-y: Beazley 1956, pp. 407-409; 1963, pp. 196-219; 1971, pp. 177, 341; 1974; Cardon 1977, pp. 6-189; Kurtz and Beazley 1983; Oakley 1997, p. 96-97.

⁴⁴⁹ i.e., 192 to 212 pots (omitting and including 'manner') / 1% rec. / 25 years = 768 to 848 p-y: Beazley 1963, pp. 483-495; 1971, p. 379; Benson 1999, pp. 1, 276-278, 311-492.

annually over 35 or 40 years (below, Figure 7.5).⁴⁵⁰ His major contemporary, the Phiale Painter, decorated about 780 to 840 vases annually over 25 years.⁴⁵¹ Because all of these artists painted vases with similar profiles, Oakley argues they were all part of a single workshop with four ‘major’ potters associated with the Achilles Painter and a large number of ‘minor’ painters, potters, and temporary collaborators.⁴⁵² Drawing together all the painters associated by Oakley with the workshop, there are about 1,850 pots attributed to 37 painters and groups. Over the 75-year period of activity of the workshop from ca. 500 to 425 B.C., about 2,450 vases were painted annually.⁴⁵³ Looking more carefully at the hands, only the four painters already discussed have more than 200 attributed vases each. Nine more painters have lesser but significant vase counts, whereas the remaining 24 or more individuals have fewer than 20 attributed vases apiece and together received less than 10% of the workshop’s attributions.⁴⁵⁴ Most of the latter were either minor hands or painters who normally worked with other groups.⁴⁵⁵

Viewed as a whole workshop, it appears that three painters were employed simultaneously, each decorating about 820 vases annually. These included a primary painter, one or two regular associates, and a third or fourth temporary or apprentice

⁴⁵⁰ i.e., 306 to 346 pots (omitting and including ‘near’) / 1% rec. / 40 years = 765 to 865 p-y: Oakley 1997, pp. 5-9, 114-170. However, Oakley attributes only 12 vases to the ‘Very Early’ and ‘Very Late’ phases, meaning the period when the Achilles Painter was active full time might have been only 35 years, equivalent to 874 to 989 p-y. Under the stylistic chronology of early through late phases in the painter’s technique, his productivity appears to peak between 450 and 430 BC: Oakley 1997, pp. 5-7.

⁴⁵¹ i.e., 196 to 210 pots (omitting and including ‘near’) / 1% rec. / 25 years = 784 to 840 p-y: Oakley 1990, pp. 2, 67-93, 96-97. Oakley dates most of his works to 440-430 BC on stylistic grounds, which would place his output over 1100 p-y for the decade: Oakley 1990, pp. 3-7.

⁴⁵² Oakley 1990, pp. 58-66, 1997, pp. 96-113; also see Beazley 1956, p. 409; 1963, pp. 986-1013; 1971, pp. 437-441.

⁴⁵³ i.e., 1850 pots / 1% rec. / 75 years = 2467 p-y: Beazley 1963, pp. 529-534, 657-662, 816-820, 1080-1086, 1161-1170; 1971, pp. 403-404, 420-421, 459; Oakley 1990, pp. 63-65; 1997, pp. 96-113. This reckoning includes 100 pots to approximate the contributions by outsiders and ‘loosely connected’ hands in Oakley 1997, pp. 105-109.

⁴⁵⁴ i.e., Alkimachos, the Cassel Painter, the Clio Painter, the Dwarf Painter, the Nikon Painter, the Painter of Munich 2335, the Painter of the Yale Lekythos, the Persephone Painter, the Providence Painter.

⁴⁵⁵ Oakley 1997, pp. 97-109.

<hr/>			470 BC
Berlin Pt.	Providence Pt. Hermonax Achilles Pt.	Alkimachos Pt. Nikon Pt. + 2 minor hands	
<hr/>			460 BC
Achilles Pt.	Providence Pt. Hermonax	+ 5 minor hands	
<hr/>			450 BC
Achilles Pt.	Phiale Pt.	+ 8 minor hands	
<hr/>			440 BC
Achilles Pt.	Phiale Pt.	Pt. Munich 2335 + 11 minor hands	
<hr/>			430 BC

**Figure 7.3 Painters in the Berlin Painter and Achilles Painter workshop
(after Oakley 1997, p. 112 chart 9)**

painter working for short terms (Figure 7.3). The first painter changed only once in the workshop's history, from the Berlin Painter to the Achilles Painter. The two had the longest careers and are regarded as the most skillful and influential draftsmen of the group. Three or more painters with career lengths shorter than 25 years, such as Hermonax or the Phiale Painter, were associates. The many temporary or apprentice painters on average decorated a number of vases equivalent to only two years of full-time work. Doubtless the workshop fluctuated in size from year to year, but with three painters on average, the annual productivity would be 820 vases per year for the entire career of the workshop,⁴⁵⁶ which is exactly the same rate calculated for the four prominent painters whose careers are approximately dated.

All of these painters decorated large pots and preferred relatively simple compositions with only two or three figures, which might explain their elevated productivity relative to the early black-figure vases by Nikosthenes. Overall, despite

⁴⁵⁶ i.e., 1850 pots / 1% rec. / 75 years / 3 ptrs. = 822 p-y / ptr.

the potential variability in the recovery rate for individual painters and workshops⁴⁵⁷ and the uncertainties of the full time span of individual careers, the annual production rates for the painters of large red-figure vases and the most prolific cup-painters are remarkably consistent. The data suggest individual painters typically decorated between 730 and 990 vases per year. Taking a conservative estimate of 800 vases, the annual productivity for red-figure painters is actually greater than twice that assumed by Cook when he estimated that 100 painters were active simultaneously. At the elevated rate for individual productivity, fewer than 45 painters working full time could have decorated all of the Attic red-figure pottery. The rate of production may not have been constant, and in reality the number of painters might have fluctuated between 40 and 50 or more. Of the 750 hands and groups identified by Beazley, painters would have worked on average for only about 9 full years over their painting careers rather than the 25 assumed by Cook. Individual painters and potters appear to have moved among different workshop groups, and the majority worked less than a decade as painters.⁴⁵⁸

Although an Attic painter might have painted at least 800 pots a year, unfortunately this figure cannot be compared directly to any ethnographic studies. No tradition with comparable decoration to Attic red-figure and black gloss has survived. The “production step measure” proposed by Feinman, Upham, and Lightfoot compares labor investment in pottery without specific timing data, but this method is not well suited for cross-cultural comparisons involving substantively different technologies like ancient Greek black gloss and modern glazes.⁴⁵⁹ It might be possible to reconstruct the time requirements of preparing black gloss and painting figures with replication experiments, although such a study does not yet exist.

⁴⁵⁷ Oakley 1992, pp. 198-199.

⁴⁵⁸ Arafat and Morgan 1989, pp. 327-329; Oakley 1997, pp. 109-113; Scheibler 1986, p. 789.

⁴⁵⁹ Feinman, Upham, and Lightfoot 1981, pp. 873-874.

However, the prices on some Attic pots provide a useful check on the productivity rate for painters. The prices of Attic pottery during the fifth century B.C. are known from epigraphic sources, primarily by trademarks inscribed or painted on the feet of pots which have been studied by Amyx and Johnston.⁴⁶⁰ Most of the several-dozen price graffiti were inscribed at the workshop on vases destined for export to Italy.⁴⁶¹ Consequently, they reflect only the maximum revenue the Attic workshop might have obtained from a completed pot, although the prices at a local Athenian market might have been slightly lower. The pot prices may be compared to the daily wage of an Athenian laborer. A skilled artisan is generally assumed to earn about one drachma a day, unskilled laborers received at least three obols, and slaves might have been maintained for only one or two obols a day.⁴⁶² The price of a fifth-century pot indexed against the daily wages of Athenian artisans is an independent test of the productivity rates indicated by the attribution data.

First, it should be noted that in arguing that Attic pottery was an insignificant, cheap commodity in Mediterranean trade, Gill and Vickers⁴⁶³ recently presented controversial readings of low prices from several graffiti of Attic pots.⁴⁶⁴ Their arguments have been forcefully refuted, although Johnston's recent addendum to his study of trademarks on Attic pottery includes some corrected price readings.⁴⁶⁵ Typical examples for highly-regarded painters are a 25-cm-high red-figure pelike marked 3.5 obols painted with two figures by the Achilles Painter (Figure 7.5)⁴⁶⁶ and a

⁴⁶⁰ Amyx 1958, pp. 275-280, 287-307; Johnston 1979, 2006.

⁴⁶¹ Johnston 1979; 1991, pp. 219-228.

⁴⁶² Amyx 1958, pp. 306-307; Johnston 1991b, p. 224; Sparkes 1991, p. 130; Vickers and Gill 1994, p. 33.

⁴⁶³ Gill 1988a, 1988b, 1991; Gill and Vickers 1990, 1995; Vickers and Gill 1994.

⁴⁶⁴ Gill 1991, pp. 31-32; Gill and Vickers 1995, pp. 228-31; Vickers and Gill 1994, pp. 85-89.

⁴⁶⁵ Johnston 2006. Also see: Boardman 1988a, 1988b, 1996; Johnston 1991a; Oakley 1999; Robertson 1985, 1992, pp. 4-5.

⁴⁶⁶ Johnston's 2B,9a (Oxford, Ashmolean Loan 399), discussed in: Johnston 2006, p. 21; Vickers and Gill 1994, p. 85, argued for a price of 0.88 obols. Oakley observes that the reading of this particular graffiti is uncertain, but the price of 3.5 obols is at least similar to other vessels: Oakley 1997, pp 14-16.



Figure 7.4 (above) Belly amphora, Berlin Painter, 52 cm high (Louvre CA 2981); **(below)** price graffito 10F,21 (Johnston 1979, fig. 12p)

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Figure 7.5 (above) Pelike, Achilles Painter, 25 cm high (Ashmolean 399: Oakley 1997, pl. 33B); **(below)** price graffito 2B,9a (Johnston 2006, pl. D)

ΑΤΙΕΛΗΗ

52-cm-high belly amphora marked 7 obols painted with two figures by the Berlin Painter (Figure 7.4).⁴⁶⁷ The most expensive graffiti appear on a pair of red-figure hydrias close to 50 cm tall with complex multi-figure scenes priced 18 obols (3 drachmas) each (Figure 7.6).⁴⁶⁸ Most of the smaller pots cost less than an obol and range downward to the plain black gloss oxybapha (small handleless bowls) worth only 1/20 obols apiece.⁴⁶⁹

⁴⁶⁷ Johnston 10F,21 (Louvre CA2981): Johnston 1979, 2006.

⁴⁶⁸ Johnston 21F,8 (St. Petersburg St. 1206, 48.5 cm high) and 18C,63 (Syracuse 23912, 47 cm high), discussed in: Johnston 1979, p. 35; 2006, p. 21.

⁴⁶⁹ Johnston 14F,4 (London E504), discussed in: Johnston 1978, p. 223; Johnston 1979, p. 35.



Figure 7.6 Hydria, Manner of the Peleus Painter, 47 cm high (Matheson 1995, p. 202 pl. 156)



Figure 7.7 Faience jar, Nabeul (Maurières and Cambon 2002, p. 80 NA85)

In contrast to the characterization of Gill and Vickers, individual pots with red-figure decoration appear to have been expensive to produce.⁴⁷⁰ We do not know the exact wages, but it is plausible that a highly skilled and literate vase painter could earn one drachma a day. Presumably, a master potter would command a similar wage, whereas unskilled assistants might be paid less. There is insufficient research to estimate the time required for various stages of the production of a red-figure pelike or belly amphora, and the overhead costs for operating a fifth-century ceramics workshop and kiln are also unknown. Although the economics are slightly different for faience and the documentation is unfortunately incomplete, an interesting comparison is the faience industry in North Africa. Potter and faience painter were separate roles in Fes and Nabeul, and potters would turn over batches of biscuit-fired vases for painting.⁴⁷¹

⁴⁷⁰ Boardman 1996, p. 124. I reject out of hand Gill and Vickers' idea that figural decoration contributed nothing to the cost of a vessel, because it assumes vase-painters were not paid for their labor: Gill and Vickers 1995, pp. 230-231.

⁴⁷¹ Bel 1918, pp. 200-201; Lisse and Louis 1956, pp. 175, 232. Also see Lightbown and Caiger-Smith 1980.

The faience painters earned slightly higher wages than potters, and the painter seems to have taken about half the sale price of each vase when contracting with an otherwise independent pottery workshop. If anything, faience is a more demanding and expensive technology than Attic black gloss, given the considerable trouble of preparing pigments for glazes and the expensive second firing for faience (Figure 7.7). Likewise, an Attic painter is unlikely to have kept over half the sales price of a vase. It may be assumed a painter would invest the labor in its decoration merited by his earnings of no more than half the sales price of a pot. In other words, the pelike by the Achilles Painter should have earned him less than 2 obols, and the belly amphora by the Berlin Painter less than 3.5 obols, even ignoring the fact that the height of the belly amphora would give the potter reason to demand a proportionately greater share of the sale. Painters would need to decorate at least two or three large pots a day to earn as much as skilled Athenian masons or sailors, and probably more if they did not take home as large a fraction of the vase's cost. This discussion cannot advance further without estimating how fast the Berlin Painter worked, but at these prices he must have been able to paint many figures in a day.

The price data may be compared directly to the annual rate of 800 pots for a specialist painter. Counting just the vases with red-figure decoration from Johnston's compilation of price graffiti, the weighted average price of large and small vases is about 3.3 obols.⁴⁷² Again, this suggests that to earn a skilled artisan's wage, a full-time painter would need to decorate either three or four pots every day, a larger number of small cups and bowls, or one or two large kraters and hydrias.⁴⁷³ Although this

⁴⁷² See Johnston 2006, pp. 22-23. The majority of the pots are red-figure, and I have omitted the "uncertain, various" category. For large open and closed vessels, there are 24 prices averaging 6.1 obols; for small vessels, 19 prices averaging 0.54 obols. The overall average price of 3.7 obols should be weighted so small and large vessels are counted equally, which reduces the overall average cost to 3.3 obols.

⁴⁷³ Because the potting and firing costs vary dramatically depending on the size and quality of the vessel, I have not attempted to estimate a "per figure" price for painters.

average price from the graffiti may not be exactly representative of the average size and decoration of all the red-figure pottery in general, a painter probably would need to decorate four “typical” pots in Beazley’s lists each day. Consequently, a painter would need about 200 days to decorate the 800 pots indicated by the quantitative analysis of attributed sherds. This length of time is surprisingly close to the typical seven-month season for many Mediterranean potters that is dictated by the climate, and it corresponds closely to DeLaine’s annual 220-day season for brick makers and builders at the Baths of Caracalla.⁴⁷⁴ The margins for error are high in this calculation, but the convergence of the price and attribution data nevertheless is a compelling indication that fewer than 50 vase painters were working simultaneously in the entire Attic pottery industry.

7.B.2) *Athenian potters*

Although the process of red-figure painting is incompletely understood, the throwing and firing of the Attic vases can be directly compared to the ethnographic record. Noble, Schreiber, and others provide valuable insight into the ancient production process, and their descriptions show that Attic pots, although highly finished, could be manufactured rapidly. Many techniques were challenging, including the elaborately turned profiles, the high degree of secondary polish,⁴⁷⁵ the levigated gloss paints, the reduction firing,⁴⁷⁶ the use of special coloring agents and non-ceramic appliqués,⁴⁷⁷ and of course the elaborate figural decoration itself. On the other hand, most components of the vases were thrown on a wheel rotating at high speed,⁴⁷⁸ and large pots were joined from two or three separately-thrown sections. The kyathos and

⁴⁷⁴ DeLaine 1997, pp 105-106.

⁴⁷⁵ Noble 1988, pp. 99-121; Richter 1923, pp. 1-47; Schreiber 1999, pp. 39-48.

⁴⁷⁶ See below, note 594.

⁴⁷⁷ e.g., Cohen 2006, pp. 8-15; Noble 1988, pp. 121-147.

⁴⁷⁸ See below, notes 511 and 512.

perhaps other small forms may have been thrown from “the hump,” where a series of pots were thrown in rapid succession from a tall cone of clay centered on the wheel.⁴⁷⁹ The potters may have been more careful in finishing and polishing their wares, but the basic potting and construction techniques did not stray far from most pottery traditions centered on high-speed throwing. Consequently, for most red-figure Attic pottery, more time was probably invested in its decoration rather than its shaping.⁴⁸⁰

Annual production counts for wheel-based potters may be obtained from only a few ethnographic studies. The expected productivity of individual potters has been examined within the context of the specialization-standardization hypothesis. Initially proposed by Rice,⁴⁸¹ the hypothesis predicts that pots made in large quantities by specialist potters will exhibit a high degree of standardization and, consequently, ancient pottery can reveal producer specialization.⁴⁸² While many specialization studies are limited to specific wares, some cross-cultural patterns have been identified. For example, the dimensions of pots thrown by specialists are significantly more standardized than those thrown by part-time potters.⁴⁸³ A recent survey by Roux places the threshold for “large-scale output” at more than 14,000 standardized vessels per year for a full-time potter throwing relatively small jars or pitchers on a high-speed wheel.⁴⁸⁴ The standardization of Attic pottery has not been analyzed quantitatively using these methods, but, considering how elaborate the vases are, there is no question that Athenian potters were highly skilled specialists.

⁴⁷⁹ Schreiber 1999, pp. 145 (Kyathos), 278. The technique has been documented as early as MM II on conical cups: Gillis 1988.

⁴⁸⁰ On the significant investment of time in the decoration of pottery in general, see, e.g.: Feinman, Upham, and Lightfoot 1981; Hagstrum 1988.

⁴⁸¹ Rice 1981.

⁴⁸² Costin 1991, pp. 3-4, 33-36; Stark 1995; Underhill 2003.

⁴⁸³ Eerkens 2000; Eerkens and Bettinger 2001; Roux 2003; Roux and Corbetta 1989.

⁴⁸⁴ Roux 2003, p. 770. See also Arnold 1985, pp. 208-210.

The productivity of a potter varies with the size of the pot, as demonstrated by a few examples from the Mediterranean. In Morocco, annual production ranged between 1,500 and 10,000 vessels per potter in a survey of many small workshops, while in Spain, a full-time potter in the nucleated workshops at Salvatierra de los Barros or Agost could throw about 5,000 large water jars over a year.⁴⁸⁵ Toward the upper end of the scale, a potter in the well-organized workshops and manufactories at Bailén could throw 25,000 to 50,000 simple pots of various sizes during the seven-month season.⁴⁸⁶ Bailén should be located at the upper end of attainable productivity in antiquity, because in 1955 it still retained many traditional features, but its potters had already been pressured to compete with highly mechanized manufactories like those at La Rambla.⁴⁸⁷ A single potter in the Egyptian workshops at Deir el-Gharbi could produce close to 200 medium-sized water jars per day with the help of several assistants,⁴⁸⁸ and potters in Fes could throw 60 to 200 pots a day depending on the dimensions of the vessel.⁴⁸⁹ Working just 200 days, the potters could make 12,000 to 40,000 vessels in a year. These productivity rates accord well with the mid third-century A.D. leases of pottery workshops recorded on three Oxyrhynchus papyri. Potters were expected to finish between 15,300 and 24,000 wine jars in the year of the lease to turn over to the landowners, although the total number of workers is not specified.⁴⁹⁰

Generally, the longest production times are associated with vessels more than 40 cm tall like water jars and storage amphoras, where potters are forced to construct

⁴⁸⁵ Vossen 1984, pp. 343 (Salvatierra de los Barros), 354 (Agost), 369-370 (Morocco). The potters of Salvatierra de los Barros are compared to those of Athens by Hannestad 1988, pp. 223-224.

⁴⁸⁶ Curtis 1962, p. 488; Vossen 1984, pp. 349.

⁴⁸⁷ Curtis 1962, pp 500-502.

⁴⁸⁸ Lacovara 1985, p. 52.

⁴⁸⁹ Bel 1918, p. 198.

⁴⁹⁰ Cockle 1981. The payment for these jars could have purchased enough wheat for an extensive crew: pp. 96-97.



Figure 7.8 Djerba: *sefrî* (Combès and Louis 1967, ph. IV.4)



Figure 7.9 Thrapsano potters: *pithari* (Xanthoudides 1927, pl. XXI)

the jars in sections. For the largest pots, a high rate of production is attained only by working on many jars simultaneously, raising a section of one while waiting for others to dry. In southern Djerba at Guellala, a Tunisian potter could throw about 9,000 small- and medium-sized vessels over a year on the wheel, but a jar maker created only about 1,800 to 2,000 large storage vessels using a slower turntable (Figure 7.8).⁴⁹¹ The Djerba storage jars are similar to the famous *pitharia* of Crete, which were created by teams of itinerant potters from Thrapsano (Figure 7.9).⁴⁹² Productivity of a master potter and his assistants was limited to fewer than 500 jars within a 100-day season,⁴⁹³ although if they had been active for every favorable month for potting in the

⁴⁹¹ Combès and Louis 1967, pp. 269-271, where potting occurs for roughly 7 months out of the year.

⁴⁹² Hampe and Winter 1962, pp. 1-46; Valianos and Padouva 1986; Voyatzoglou 1973, 1974, 1984; Xanthoudides 1927.

⁴⁹³ Hampe and Winter 1962, p. 20; Voyatzoglou 1974, p. 13. Itinerant teams left Thrapsano for the full summer during the *ventema* of slightly more than 100 days, although much of this time was devoted to travelling, setting up workshops, negotiating trade deals, and producing other varieties of jars: Voyatzoglou 1984, p. 131. Voyatzoglou reported that only 40 days were devoted to throwing jars with firing taking place afterwards, whereas Hampe and Winter described an eight-week season with firings intermingled with throwing: Voyatzoglou 1974, p. 19; Hampe and Winter 1962, pp. 27, 32. The total

year, they might have created 2,000 vessels standing over a meter tall.⁴⁹⁴ Thus, large storage jars were the most challenging pots to throw and required the most labor, and it is no surprise that the ancient Greek proverb to “learn the potter’s craft on the pithos” was applied to those “who skip the first lessons, and immediately attempt greater things.”⁴⁹⁵

The majority of Attic figure-decorated pottery was much smaller and could have been produced at higher rates than the exceptionally large Cretan storage jars. Attic pots were thrown on high speed wheels, and secondary operations like joinery and polishing could be performed rapidly as well. Clearly Attic black gloss potters were highly skilled specialists, and even at a relatively low rate of production compared to the ethnographic survey, an individual Athenian potter might throw several thousand larger pots a year or perhaps tens of thousands of smaller cups and bowls. Regardless, an Attic potter’s annual productivity should be in the thousands, which is significantly higher than the estimated productivity for painters.

7.B.3) *Workshops at Athens*

At this point, it is possible to consider the overall scale of production in Athens, beginning with painters and extrapolating the number of associated craftsmen. The first question is how many potters there would have been relative to painters. Attic painters often are grouped around one or two potters within a workshop,⁴⁹⁶ and the relative importance of potters may be reflected by the greater overall frequency of

productivity over a season was reduced by frequent mishaps during the drying and firing: Hampe and Winter 1962, pp. 39-40.

⁴⁹⁴ Without considering losses, a team with one master could produce 10 to 16 large jars a day: Hampe and Winter 1962, p. 32; Voyatzoglou 1974, p. 19; 1984, p. 131. An annual production for 200 days with 10 successfully fired jars per day is comparable to the fixed installations in Djerba.

⁴⁹⁵ Zenobius 3, 65, presented along with three similar proverbs by Richter 1923, pp. 92-93.

⁴⁹⁶ Beazley 1944, pp. 116-119; Webster 1972, pp. 14-41. Oakley proposes an alternative arrangement: below, note 498.



**Figure 7.10 Hydria, Leagros group
(Munich 1717: Xatzedemetriou 2005, pl. 10 K39)**

their signatures over painters.⁴⁹⁷ The workshop master is often assumed to be a potter who employed several painters, which seems to have been the case for Nikosthenes.⁴⁹⁸ Webster observes that identified painters are far more numerous than potters.⁴⁹⁹ Scheibler believes that most workshops had only one or two wheels and multiple painters working with each potter, although the collaborations were fluid over individuals' careers.⁵⁰⁰

The representations of pottery workshops on vases are generally consistent with this picture. Most are only vignettes showing a single stage of the production process, but six scenes show either throwing or painting occurring in a workshop along with other activities. Best known is the workshop scene on a hydria attributed to

⁴⁹⁷ Beazley 1944, p. 116. Despite the high frequency of potter signatures, painters seem to outnumber potters by attributions: Webster 1972, p. 2. Unfortunately, the interpretation of this compilation is problematic: Eisman 1973, p. 448. Even the interpretation of "epoiesen" signatures as belonging to potters has been questioned: Cook 1971; Robertson 1972; Eisman 1974. Vickers and Gill have argued for a radically different interpretation of both types of signatures: Vickers and Gill 1994, pp. 154-165.

⁴⁹⁸ Scheibler 1984, pp. 131-132; Seeberg 1994, p. 163; Tosto 1999. Note, however, that Oakley implies there were four 'major' potters active with only two major painters at the Achilles Painter's workshop, although it is less clear from the evidence whether these are truly equivalent to four potters throwing in parallel: Oakley 1997, pp. 91-95, 100, 110.

⁴⁹⁹ Webster 1972, pp. 2-3.

⁵⁰⁰ Scheibler 1983, p. 116; 1986, pp. 789, 799-800.

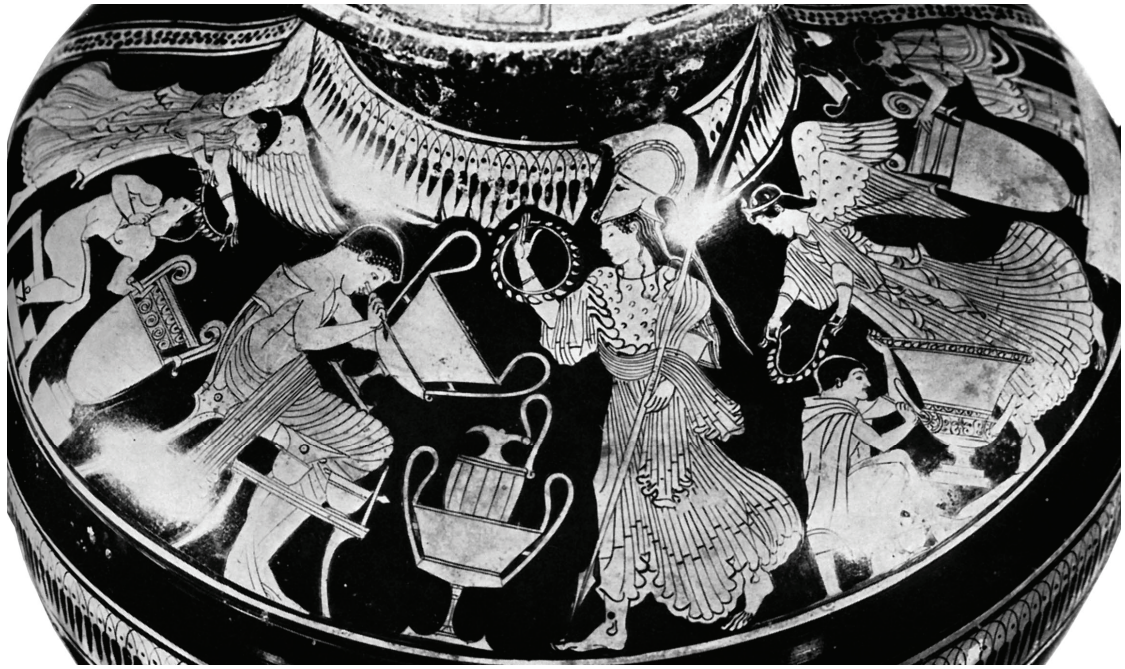


Figure 7.11 Shoulder of the Caputi hydria (Milan: Noble 1988, fig. 74)

the Leagros group where eight figures engage in different tasks along the production of large storage jars, including a potter and his assistant throwing a jar at the wheel (Figure 7.10).⁵⁰¹ A fragment by the Painter of the Louvre Centauromachy depicts a potter and his assistant at the wheel near to a painter.⁵⁰² A painter and two assistants carrying pots are depicted on a vase in the Ashmolean museum.⁵⁰³ The Caputi Hydria attributed to the Leningrad Painter depicts four painters—an adult male, two boys, and a female—decorating large kraters in the presence of Athena and two Nikes (Figure 7.11).⁵⁰⁴ A vase from the acropolis shows a kylix painter, a bronze worker, a sculptor, and assistants presided over by Athena.⁵⁰⁵ The last is a crudely-painted Boiotian cup with a comical depiction of several craftsmen inspecting pots.⁵⁰⁶ The list is too short to

⁵⁰¹ Munich 1717: Xatzedemetriou 2005, p. 210 (K39). Also see Arafat and Morgan 1989, p. 317; Beazley 1944, p. 88; Richter 1923, pp. 64-65 (no. 1); Scheibler 1986, pp. 794-798.

⁵⁰² Athens 739: Xatzedemetriou 2005, p. 211 (K50). Also see Beazley 1944, pp. 96-97; Richter 1923, p. 66 (no. 3).

⁵⁰³ Ashmolean 562: Xatzedemetriou 2005, pp. 211-212 (K51). Also see Scheibler 1986, pp. 798-799.

⁵⁰⁴ Milan, Caputi hydria: Xatzedemetriou 2005, p. 211 (K47). Also see Arafat and Morgan 1989, pp. 317-319; Beazley 1944, pp. 93-95; Richter 1923, pp. 70-71 (no. 1).

⁵⁰⁵ Athens NM 166: Xatzedemetriou 2005, p. 210 (K42). Also see Richter 1923, pp. 72-73 (no. 3).

⁵⁰⁶ Athens NM 442: Xatzedemetriou 2005, p. 212 (K53). Also see Beazley 1944, pp. 100-101.

be conclusive, but it is perhaps significant that even in the large workshop scene by the Leagros group only one wheel is depicted, whereas four painters are at work in the scene by the Leningrad painter. However, the presence of deities and the lack of any other workshop activities in the latter scene argues against interpreting it too literally.

A final clue comes from a comparison to the faience industry, where potting and painting were separate jobs. Most of the faience workshops in Fes made enamel tiles, but Bel reported that 5 potters and 14 decorators were making faience vases in 1916, later noting that a single painter could not keep pace with a single potter at his workshop.⁵⁰⁷ The editors of Piccolpasso's mid sixteenth-century treatise on majolica suggest a typical workshop in Umbria would have had a manager with seven or eight workers: two throwers, two or three painters, and three employees providing other support.⁵⁰⁸

These indications admittedly are vague, but in light of the relatively low estimated productivity for Attic painters, it is likely that that a potter with his support staff would be capable of supplying two or three additional painters. In this scenario, the maximum of 50 painters would have been supplied with vases by only 20 to 25 potters.

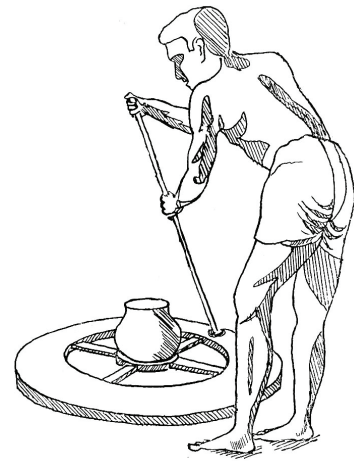
There are firmer grounds for estimating the number of employees grouped around each potter, because this information is reported in many ethnographic studies. At the workshop and nucleated industry level of production it is typical for several assistants or apprentices to perform menial jobs like mining and preparing clay, allowing the experienced throwers more time at the wheel. There were two or three assistants for two throwers (for a ratio of assistants to potters of 1:1 to 1.5:1) in the workshop industries exporting undecorated plain wares at Salvatierra de los Barros

⁵⁰⁷ Bel 1918, pp. 188 note 1, 200-201. Also see above, note 471.

⁵⁰⁸ Lightbown and Caiger-Smith 1980, pp. xxi-xxiii.



**Figure 7.12 Little master lip cup, turntable
(Karlsruhe, Badisches Landesmuseum 67.90:
Xatzedemetriou 2005, pl. 9 K37)**



**Figure 7.13 Stick wheel
(Saraswati and Behura
1966, p. 20 fig. 1.20)**

and Agost in Spain.⁵⁰⁹ Workshops in Bailén produced large quantities of lead-glazed utility wares with only two assistants for two throwers (1:1).⁵¹⁰ Thus in a high-speed production environment, it is possible for a shop to operate with only one assistant preparing clay for a potter.

All of the commercial Mediterranean workshops visited by ethnographers used kick wheels, allowing the potter to throw vessels alone as long as he had a steady supply of wedged clay. However, this form of wheel did not exist in Classical Greece, where high-speed throwing was accomplished instead on heavy turntables fixed low to the ground (Figure 7.12).⁵¹¹ This technique is relatively inefficient because the turntable is unstable, and an assistant is required to keep the wheel spinning rapidly.⁵¹² Although some Mediterranean households still use slow turntables for domestic production, full-time potters replaced the turntable with the kick wheel. Some potters still use a version of the turntable in India and a few regions of Pakistan, but they are

⁵⁰⁹ Mossman and Selsor 1988; Vossen 1984, pp. 342-343, 354.

⁵¹⁰ Curtis 1962, pp. 488, 491; Vossen 1984, p. 349. The largest workshop had 12 wheels and 8 assistants, but here the owner used a truck to supply clay.

⁵¹¹ Rieth 1952; 1960, pp. 38-44.

⁵¹² Powell 1995.

able to work alone by accelerating the wheel with a stick (Figure 7.13).⁵¹³ There is no evidence that the Classical Greeks knew this technique. Instead, young apprentices are depicted turning the wheel for potters on four Attic vases as well as some earlier Egyptian representations.⁵¹⁴

The operation of a turntable is exceptionally well documented for the Thrapsano pithos makers. Out of the team of six craftsmen, a master and a “wheeler” worked together throughout the day to throw the large storage jars.⁵¹⁵ At times, the “second master” threw smaller pots on his own, and the three other craftsmen assisted in the transportation and preparation of the clay and firing. Thus, three assistants were needed for two throwers (1.5:1) as well as one more assistant for the large jars on the turntable (above, Figure 7.9). A similar ratio may be observed in the small nucleated workshops at Guellala in Djerba, where an individual potter periodically worked with a transporter and another assistant for preparing clay (2:1). The rhythm of the production process was different for the large storage jars, because potters worked with another full-time assistant at the turntable and transportation costs were relatively high.⁵¹⁶ One of the highest ratios of assistants to potters appears at Deir el-Gharbi, where two to three assistants were employed for each potter (2:1 to 3:1), although here large storage jars were thrown on the wheel at very high speeds.⁵¹⁷

In review, it seems unlikely that Attic potters would generally have exceeded the 1.5:1 ratio for assistants, because 2:1 and 3:1 is documented only for the highly specialized production of large storage jars. However, the turntable technology used

⁵¹³ Rye and Evans 1976, pp. 87, 116; Saraswati 1978, pp. 16-19; Saraswati and Behura 1966, pp. 4-22. An assistant turns the wheel for the potter in a few regions. This system is reported to have survived among a few workshop industries in Morocco: Vossen 1990, pp. 263-267, 311 (wheel types 2, 4).

⁵¹⁴ Greece: Karlsruhe 67/90 (K37), Munich 1717 (K39), Caltagirone 961 (K49), Athens 739 (K50); Xatzedemetriou 2005, pp. 209-212. Egypt: Powell 1995, pp. 318-320; Rieth 1960, pp. 28-34.

⁵¹⁵ Hampe and Winter 1962, pp. 20-21, 25-32; Voyatzoglou 1974, pp. 18-19; 1984, pp. 131-139.

⁵¹⁶ Combès and Louis 1967, pp. 81-98, 228-232, 255-258.

⁵¹⁷ Lacovara 1985, p. 52; Nicholson and Patterson 1985b, pp. 224-233; 1985b. Although a separate group, the miners appeared to have earned a relatively minor fraction of the sales price of each jar.

by ancient potters requires an extra apprentice as “wheeler,” meaning each potter would likely have a total of two or three assistants (2.5:1) in addition to painters. This scenario is reminiscent of Bel’s brief description of the organization at Fes. There workshops making glazed faience pottery had a minimum of five craftsmen: a potter, his three assistants, and a painter; and workshop owners also paid a small amount for the mining and transportation of clay from the quarries by separately organized laborers.⁵¹⁸ If there were no more than 25 potters in Attica producing vases destined for red-figure decoration, they would have employed only about 60 assistants. Together with about 45 painters, the total population would have averaged about 130 craftsmen. Over the fifth-century B.C., the red-figure industry might ranged between only 100 to 150 craftsmen, far fewer than the 400 or 500 suggested by Cook.⁵¹⁹ If many of the painters had time to throw some pots as well, the maximum population might have been only 100 craftsmen.

The Penthesilea Painter’s group was among the largest workshops, with perhaps five to seven painters. The painters primarily decorated cups, which might be thrown comparatively quickly, so even if the painters did not throw their own pots, only one or two potters could have supplied them all. The requirements for clay and kiln space were comparatively low for cups, and the whole workshop, including painters, potters, and their assistants, probably had between eight and fifteen craftsmen.⁵²⁰ The unusual practice where two painters collaborated on a single cup also suggests these workers were narrowly specialized rather than participating in the full production sequence. If indeed all these painters were employed in a single workshop specializing in cups, then the Penthesileans are best characterized as a small

⁵¹⁸ Bel 1918, pp. 61-62, 187-188, 196-197, 200.

⁵¹⁹ See above, note 422.

⁵²⁰ i.e., from a minimum of 5 painters with 3 helpers (1 full-time potter, 1 wheeler, and 1 other assistants to mix clay and to work as porters) to a maximum of 7 painters with 8 helpers (3 full-time potters, 3 wheelers, and 2 other assistants).

manufactory. This group is an exceptional case. The workshop of the Berlin Painter and the Achilles Painter produced larger vases, and its three full-time painters would have been supported by one or two full-time potters and two to four assistants, a total of only six to nine employees. It is clear from the Beazley attributions that painters frequently moved among workshops, and it is likely that individuals performed a variety of tasks along the production process throughout their careers,⁵²¹ but the roles within the workshops would be relatively stable. In all, it is doubtful that many Athenian workshops had more than twelve employees, and, even at the peak of the industry, there should have been fewer than 20 red-figure workshops.⁵²²

The Attic fine-ware industry shares several key features with many of the ethnographic accounts of nucleated industries. Red-figured and good black-gloss pottery was valuable and widely exported, indicating a steady demand for the product across the Mediterranean.⁵²³ The fifth-century workshops with six or more full-time employees are consistent with a nucleated industry. Moreover, the total population of at least 100 craftsmen in the Attic red-figure industry approaches the scale of many urban and rural nucleated industries and manufactories which were economically dependent on pottery exports. Several hundred potters were once active in workshops scattered across the Greek island of Siphnos, once famous for its skilled potters.⁵²⁴ The itinerant Thrapsano pithos makers reportedly numbered over 200 in the recent past.⁵²⁵

⁵²¹ e.g., Eisman 1974; Immerwahr 1984, p. 347; Oakley 1992; Scheibler 1983, pp. 110-111; Seeberg 1994. Also see above, note 458.

⁵²² Also see Valavanis 1997. He argues that one or two larger workshops existed at any period with up to 25 employees. The only evidence he cites to support this hypothesis is the presence of 10 different hands on a group of Panathenaic amphoras dated by archon inscriptions between 363 and 360 BC from Eretria. Although the argument is plausible, his interpretation depends entirely on the assumption that all of the painters were full-time employees of a single workshop.

⁵²³ e.g., Hannestad 1999; Osborne 2001.

⁵²⁴ Turner 1977; Wagner 1972. There were 103 workshops active before the Second World War: Wagner 1972, p. 1.

⁵²⁵ Or about 30 to 35 teams of 6 workmen: Hampe and Winter 1962, p. 3; Voyatzoglou 1974, p. 24. While not exactly engaged in export, the itinerant teams were supplying markets throughout all of Crete.

In Egypt, between 140 and 350 craftsmen worked in the water jar industry at the village of Deir el-Gharbi.⁵²⁶ The Tunisian centers were larger, with some workshops crossing the threshold for a manufactory. Almost 200 craftsmen worked at the major urban production center at Nabeul throughout the nineteenth century, and the number had swollen to over 800 by the mid twentieth century, including some very large commercial enterprises.⁵²⁷ Between 1875 and 1942, the population of craftsmen producing utilitarian pottery at two nucleated rural centers on Djerba fluctuated between 237 and 775.⁵²⁸ Many potters in each of these industries were near full-time specialists, and, likewise, a sizeable percentage of potters and painters in Attica would have been dependent on ceramic production for income throughout most of the year. Few of these workshops, however, could be represented as bearing many characteristics in common with the larger manufactories described by Peacock at Nabeul and in northern Europe.

The peak Attic population of 100 or 150 craftsmen was derived exclusively from attributed vases, although plain black gloss and coarse pottery would have represented the numerical majority of Athenian production. However, except for very large storage jars, plain wares can be produced much more rapidly than the rates for figure-decorated vases proposed here. Rather than the 2,500 red-figure vases per year produced by the six to nine craftsmen in the Achilles Painter's workshop, a potter with one or two assistants can produce from 5,000 to 25,000 vessels depending on the size and decoration. The potters in the twenty workshops hypothesized here likely threw plain black gloss pottery as well. Because the paint and firing technologies are identical in plain and figure-decorated vases, workshops could have produced both without any technical challenges. However, the data reviewed here is insufficient to

⁵²⁶ Nicholson and Patterson 1985a, p. 54.

⁵²⁷ Lisse and Louis 1956, pp. 177, 212-213; Fleury 1896, p. 191.

⁵²⁸ Combès and Louis 1967, pp. 25, 253; Fleury 1896, p. 191.

determine whether 100 to 150 craftsmen created the majority of the domestic pottery in Athens, or just the figure-painted pottery.

7.C) Pottery and tile production in Ancient Corinth

7.C.1) *Fine-ware workshops at Corinth*

How would this situation compare to seventh-century Corinth? First, it is generally assumed that pottery productivity was much lower in the Archaic period relative to fifth-century Athens. Because the quantity of sixth-century pottery is approximately half that of the fifth, Cook assumes the number of artisans in sixth-century Athens was also about half as large.⁵²⁹ This may be too drastic a correction without comparing the times needed to produce black-figure and red-figure pottery, because much of the black-figure pottery is elaborately decorated. However, the number of painters identified by Beazley is substantially lower in the sixth century, so halving the number of simultaneously active painters is not unreasonable. It is less clear how the total artisanal population would be affected, because the number of potters making plain wares is tied more to the demand in the home market, which is dependent on the population of Attica rather than external trade.

Relating the production costs of Corinthian black-figure to Attic red-figure pottery is still more difficult with the evidence published to date. Corinth participated in an extensive trade network with the west by the late eighth century B.C., and its Orientalizing pottery is found throughout the Mediterranean by the seventh century.⁵³⁰ The basic technology of Attic and Corinthian black gloss is similar, and polychrome black-figure decoration developed in the Middle Protocorinthian phase

⁵²⁹ Cook 1959, p. 121.

⁵³⁰ Amyx 1988, vol. 2, pp. 675-678; Kourou 1994; Rasmussen 1991, pp. 63-66, 78; Salmon 1984, pp. 95-116.



Figure 7.14 Lekythos, ca. 650 B.C., 9 cm high (Boston MFA 08.281)

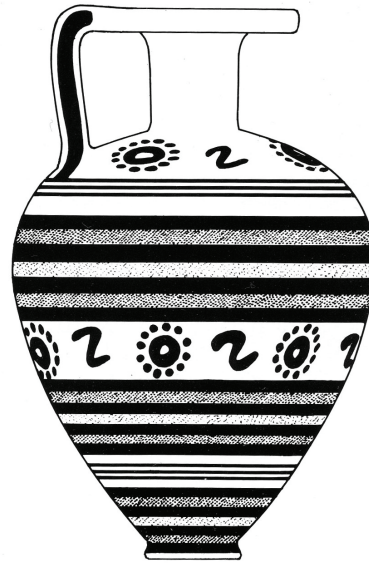


Figure 7.15 Aryballos of the Utrecht Group (Neeft 1987, p. 229 fig. 133)

(Figure 7.14),⁵³¹ which is about the time of the construction fills associated with the Old Temple at Corinth. A quantitative comparison with Athens is facilitated somewhat by the recent classifications of Corinthian pottery using Beazley's method of attributions, and scores of painters and groups are identified in seventh-century Corinth. However, the number of attributed sherds is dramatically lower than for the later Attic vases. Over the two centuries from the Early Protocorinthian through Late Corinthian, at least 3,000 vases may be attributed to about 300 painters and groups.⁵³² These attributions are extremely limited for the hundred years spanned by the Protocorinthian and Transitional periods, when about 600 vases are attributed to about 60 painters and groups, half of which belong to the final Transitional period.⁵³³ In contrast, more than 1,000 Protocorinthian subgeometric aryballoi are extant, but these widely exported pots are only categorized by shape and decorative patterns (Figure

⁵³¹ Amyx 1988, vol. 2, pp. 537-40.

⁵³² Amyx 1988, vol. 1, pp. 15-277. However, the quantities may expand rapidly with future publication, e.g.: Brownlee 2003.

⁵³³ Amyx 1988, vol. 1; Benson 1989, pp. 19-71.

7.15).⁵³⁴ Many Corinthian vases have been excavated at production areas like the Potters' Quarter, and one should expect higher counts of attributable sherds at an ancient production site than at distant importers of its wares. However, the total count of attributed vessels from Corinth is even lower than the quantity produced by the small selection of Attic red-figure painters that have been reviewed here, who were active over only about 80 years. In other words, in the present state of publication, the rate of attributions for Corinthian pottery seems very low in comparison to Attic red-figure. Any direct quantitative comparison to Athens, however, is unlikely to be reliable due to the difficulties in separating the hands of Corinthian painters.⁵³⁵

Corinthian potters during the seventh century specialized in small vases. Considering that the productivity of individual potters varies dramatically depending on the size and shape of the vessel, small Corinthian pots could have been produced more quickly than an average Attic red-figure vase. Moreover, despite the recovery of up to tens of thousands of sherds in some western colonies, the total Corinthian production on an annual basis does not appear to be very large.⁵³⁶ The recovery rate for these sherds from controlled excavations might be higher than the 1% figure assumed for all red-figure pottery. Thus, the archaeological evidence does not indicate that seventh-century Corinth supported a larger pottery industry than fifth-century Athens.

Arafat and Morgan suggest instead that the area and political organization are directly proportional to the size and complexity of the pottery industry.⁵³⁷ The Classical population of Corinth is estimated at less than half of Attica's because the area of Attica was 2.5 times greater than Classical Corinth, and Corinth's settlement

⁵³⁴ Neef 1989.

⁵³⁵ Benson 1989, pp. 9-10; Brownlee 2003; Crielaard 1999, pp. 54-55; Davison 1968, pp. 5-11.

⁵³⁶ e.g., Salmon 1984, pp. 103-109, 132-136.

⁵³⁷ Arafat and Morgan 1989, p. 325.

appears more dispersed, as if less densely populated than Athens.⁵³⁸ Even ignoring the changes in population between the seventh and fifth centuries B.C., Corinth would have had less than half the number of potters in smaller, more dispersed workshops, all else being equal. Population, however, appears to have increased over these centuries, and, although a fixed ratio is uncertain, it seems likely that the population of the fine-ware industry in seventh-century Corinth would have been no more than one third that of Classical Athens. If fifth-century Athens had fewer than 50 painters and 150 craftsmen at the peak of its red-figure industry, then fewer than 15 painters and 50 individuals in workshops scattered across the seventh-century settlement of Corinth would have produced decorated pottery.⁵³⁹

7.C.2) *Excavations of Archaic workshops in Corinth*

Excavations at pottery workshops clarify the organization of production in Archaic Corinth (Figure 6.1). Foremost is the Potters' Quarter, active between the eighth and fourth centuries B.C. at the western edge of the settlement (Figure 7.16).⁵⁴⁰ The architecture at the site, however, appears to have been primarily residential. At the time of the Old Temple's construction, several Late Geometric graves, water channels cut into the bedrock, and rubble walls provide no indication of specialized production facilities.⁵⁴¹ Long perpendicular walls of buildings erected in the late seventh and sixth centuries and the Classical Terracotta Factory are more likely to have been residential, and no kilns have been located.⁵⁴² Although pottery production at the site is confirmed

⁵³⁸ Salmon 1984, p. 165-169.

⁵³⁹ On dispersal of production sites: Benson 1983, pp. 312, 318; 1984.

⁵⁴⁰ Arafat and Morgan 1989, pp. 323-325; Benson 1984; Brownlee 2003; Stillwell 1948, 1952; Stillwell and Benson 1984; Williams 1981, pp. 412-421; 1982.

⁵⁴¹ Stillwell 1948, pp. 6-15; Williams 1982; Stillwell and Benson 1984.

⁵⁴² See above, note 413.

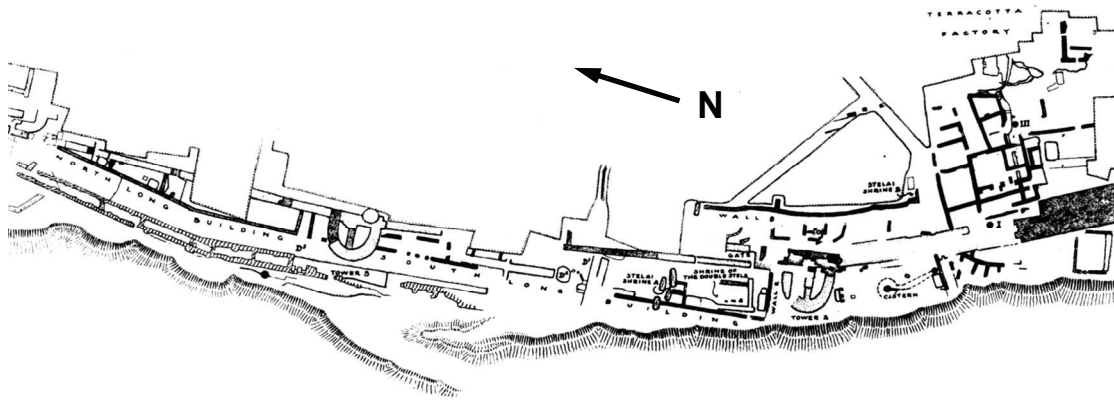


Figure 7.16 Plan of the Potters' Quarter (ca 280 m N-S: Stillwell 1948, pl. 51)

by other finds, only small workshops could have operated among or inside private houses and not big, specialized manufactories.

Large quantities of fine pottery, miniature votive pots, and figurines were recovered at the site. Wasters dated to the Late Geometric through the Late Corinthian periods and trial pieces indicate the firing of a wide variety of fine pottery in the area.⁵⁴³ Stillwell and Benson identify many hands among the figure-decorated pottery, the bulk in the Middle Corinthian period when production must have peaked (i.e., within the first three decades of the sixth century).⁵⁴⁴ From the Protocorinthian to the Transitional periods the number of attributions is small. Only eight “workshops” and eight painters or groups have been identified in pottery from this early period at the Quarter, which is approximately one seventh of the total Corinthian attributions at this time.⁵⁴⁵ However, two thirds of the identified Corinthian hands and groups are known only from their exports and have yet to be excavated in Corinth. Many forms are produced at the Potters' Quarter, but the widely-exported Thapsos ware, globular aryballoi, and certain types of kotyles are noticeably absent, indicating that other

⁵⁴³ Brownlee 2003, p. 184; Stillwell and Benson 1984, pp. 246-253.

⁵⁴⁴ Stillwell and Benson 1984, pp. 10-12.

⁵⁴⁵ Amyx and Lawrence 1975, pp. 6-11. Early and Middle Corinthian painters are better represented in the Quarter; also see Brownlee 2003.

Archaic fine-ware production centers in Corinth have not yet been located.⁵⁴⁶ Another significant product was terracotta figurines. More than 100 molds and 3,000 molded and handmade figurines have been recovered. Production commenced at the site during the third quarter of the seventh century B.C. and continued until its abandonment in the fourth century.⁵⁴⁷ Wheelmade lamps probably were produced as well, starting in the seventh century.⁵⁴⁸ The handmade and wheelmade coarse pottery, loom weights, spindle whorls, and roof tiles probably were used in the houses and not produced at the site.⁵⁴⁹

The Potters' Dump excavated in the Anaploga Well came from another production site for Archaic fine ware fifteen minutes' walk to the south of the Potters' Quarter (above, Figure 6.1).⁵⁵⁰ A concentration of discolored, bloated wasters and possible apprentice pieces from pitchers, drinking cups, neck amphoras, and kraters indicate that only wine-drinking equipment was produced and discarded here. The well was opened by the first decades of the seventh century and gradually filled in over the course of 120 years, ending in the Late Corinthian I. The Potters' Dump was deposited over the 65 years from the Late Protocorinthian through the Middle Corinthian periods.⁵⁵¹ Handmade coarse pottery was mixed throughout the well deposits but does not appear to have been manufactured nearby.⁵⁵² The fine wares are clearly distinguished from those in the Potters' Quarter. The six painters and one group in the Potters' Dump have been identified only on vases found within Corinth, whereas many exporters worked in the Potters' Quarter.⁵⁵³ With just six or more

⁵⁴⁶ Benson 1983, p. 318; 1984; Brownlee 2003, p. 181; Stillwell and Benson 1984, p. 10.

⁵⁴⁷ Merker 2003, pp. 235-236; Stillwell 1948, pp. 82-113; 1952, pp. 3-4, 25-243.

⁵⁴⁸ Stillwell 1952, pp. 244-267.

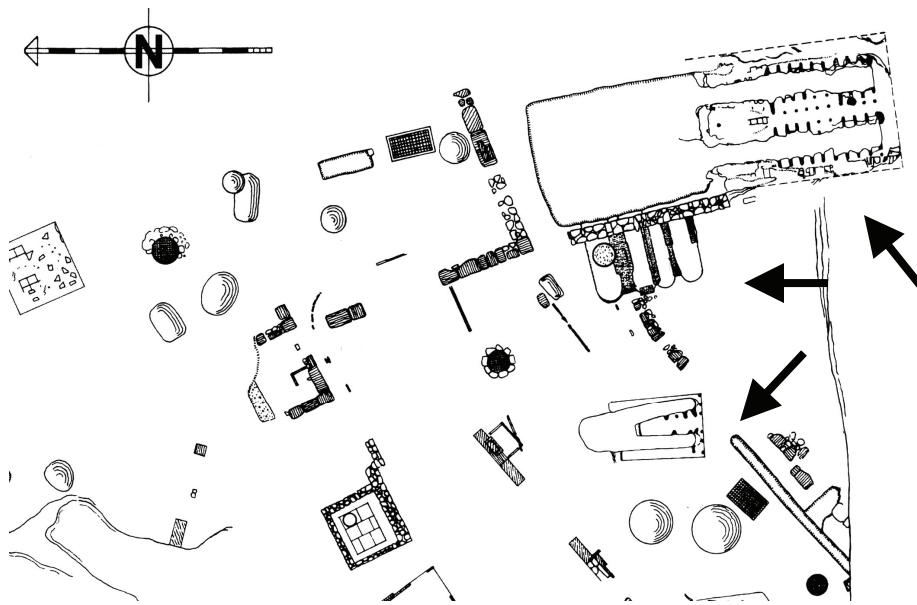
⁵⁴⁹ Stillwell 1952, pp. 268-272; Stillwell and Benson 1984, pp. 344-357.

⁵⁵⁰ Amyx and Lawrence 1975, especially pp. 63-90.

⁵⁵¹ Amyx and Lawrence 1975, pp. 63-66, 69-70.

⁵⁵² Amyx and Lawrence 1975, pp. 91-95.

⁵⁵³ Amyx and Lawrence 1975, pp. 83-90.



**Figure 7.17 Plan of the Tile Works with kilns indicated by arrows
(ca. 40 m N-S: Merker 2006, p. 6 fig. 3)**

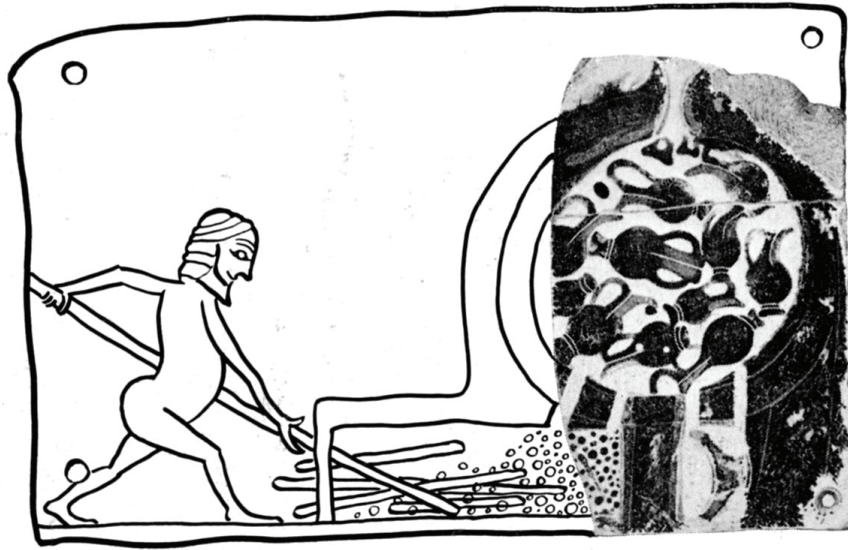
distinct hands active over 65 years, a single workshop supplying fine pottery for the home market could have produced the deposit.

At the opposite side of the settlement, the Tile Works are of particular significance to the analysis of Protocorinthian tile production. A recent publication describes the Greek finds and architectural phases from this workshop to the northeast of the city walls (above, Figure 6.1).⁵⁵⁴ Three kilns were in use between the late Archaic period and the fourth century B.C., and manufacturing at the site might have begun as early as the second quarter of the sixth century (Figure 7.17).⁵⁵⁵ The major products fired in the kilns were roof tiles. Thousands of Corinthian cover and pan tiles, decorated architectural terracottas, and architectural sculpture were recovered during the excavations, and a mold for a lion head spout confirms manufacturing at this site.⁵⁵⁶ In the sixth and fifth centuries, however, a significant number of other types of ceramic objects were produced in addition to tiles. Although there is no evidence that

⁵⁵⁴ Merker 2006. Also see: Hasaki 2002, pp. 277-284.

⁵⁵⁵ Merker 2006, pp. 3, 9-16.

⁵⁵⁶ Merker 2006, pp. 20-23, 35-42, 139-173.



**Figure 7.18 Penteskouphia plaque depicting firing
(restored from Berlin, Antikenmuseum F 893: Noble 1988, fig. 238)**

terracotta figurines themselves were created at the site, nine figurine molds found were perhaps manufactured for distribution to other workshops that made figurines.

Mortars, pestles, basins, and loom weights were likely made there as well.⁵⁵⁷

Apparently, the kilns were used to fire other objects besides tiles. All of the products are united by common fabrics and forming techniques. With the exception of a few wheelmade bowls that may not have been made at the Tile Works, every object was hand built with the aid of molds in the Corinthian “tile fabric,” a coarse paste tempered with mudstone.⁵⁵⁸

No other Archaic ceramic production sites have been studied in detail at Corinth, although a large cache of fragmentary aryballoi, skyphoi, and pyxides dating from the Protocorinthian through Middle Corinthian periods were excavated near a kiln at the Gotsi Plot.⁵⁵⁹ The Penteskouphia plaques also provide a tantalizing glimpse

⁵⁵⁷ Merker 2003, p. 241; 2006, pp. 10, 20-72.

⁵⁵⁸ Merker 2003, p. 243; 2006, pp. 17-19.

⁵⁵⁹ Hasaki 2002, pp. 334-335; Protonotariou-Deilake 1971, p. 68.

of kiln firing and other stages of pottery production in Archaic Corinth (Figure 7.18), but it is uncertain where and for what purpose these plaques were manufactured.⁵⁶⁰

7.C.3) *Organization of the ceramics industry at Corinth*

The grouping of objects produced at the Corinthian workshops is repeated at other Archaic settlements. For example, a recently excavated workshop at Phari on Thasos was active in the late Archaic period.⁵⁶¹ Like the Potters' Quarter and the Anaploga Well workshop, it specialized in wheelmade fine wares. The full range of small domestic storage and service vessels were produced at the site in addition to mortars and wheelmade lamps. Only larger amphoras and cooking wares were noticeably absent, perhaps due to their different requirements for paste and firing technology.⁵⁶² Several rows of cover and pan tiles, which were made of a coarse fabric similar to that of pottery, were found stacked against a wall, perhaps indicating tiles were manufactured there as well.⁵⁶³ They may instead have been stockpiled for repairing a building at the site. Other workshops which fabricated coarse ceramics are relevant to the discussion of Corinth. The only verified production site for Corinthian B amphoras is in fact a Classical workshop with several kilns at Figaretto in Corfu.⁵⁶⁴ Amphoras were its main product, but statuette molds, tiles, loom weights, and fine pottery appear in sufficient quantities to suggest they too might have been made on site.⁵⁶⁵ In central Crete, a survey of Hellenistic amphora workshops consistently reported smaller quantities of other types of utilitarian pottery and roof tiles mixed in with the kiln debris.⁵⁶⁶

⁵⁶⁰ See above, note 327.

⁵⁶¹ Blondé, Perreault, and Péristéri 1992, pp. 20-38; Perreault 1990, 1999.

⁵⁶² Perreault 1999, pp. 297-298.

⁵⁶³ Perreault 1990, especially p. 208.

⁵⁶⁴ Kourkoumelis and Démesticha 1997; Preka-Alexandri 1992, especially p. 50.

⁵⁶⁵ Kourkoumelis and Démesticha 1997, p. 555.

⁵⁶⁶ Empereur, Kritzas, and Marangou 1991.

Workshops in Archaic Corinth and the other centers may be divided into producers of two general categories of wares: fine pottery with gloss or matt-painted decoration, and heavier objects with a coarse fabric. Within these two technologies, workshops specializing in pottery or tiles would occasionally produce other wares. The fine-ware producers threw pots and lamps on the wheel using the same fine paste. Probably in response to seasonal demands for festivals, these workshops also created figurines. In the Archaic period figurines were produced in fine clay using an amalgamation of techniques, often attaching a molded head onto a slab-built or wheelmade cylindrical body.⁵⁶⁷ On the other hand, amphora or tile makers produced statuette molds, loom weights, and other utilitarian domestic vessels, few of which were thrown on the wheel. Ethnographers document similar technological divisions in the nucleated pottery industries of the Mediterranean. For example, guilds in Tunisia and Morocco were divided into makers of storage jars, glazed wares, and bricks; in Cyprus, potters, pithos makers, and brick makers were separate groups; and in the cases cited in Spain and Egypt, whole villages specialized in specific forms of vessels.⁵⁶⁸

The kiln is likely the primary technological constraint that determines the division of workshops between fine and coarse ware manufacturing.⁵⁶⁹ Although a potter might have gathered a variety of clays and prepared different grades of pastes to produce both black gloss pottery and roof tiles, both types cannot be fired together efficiently. For example, the carefully controlled reduction cycle for black gloss would be wasted on roof tiles. The coarse, tempered, and calcareous fabric of tiles is prone to spalling, and firing tiles at lower temperatures instead is more effective and saves fuel.

⁵⁶⁷ Merker 2003, pp. 240-241; Stillwell 1952, pp. 3, 9, 55-84.

⁵⁶⁸ North Africa: Bel 1918; Combès and Louis 1967, pp. 228, 253-254; Lisse and Louis 1956, p. 177. Cyprus: London 1989, pp. 71-73. Spain and Egypt: Vossen 1984; Lacovara 1985; Nicholson and Patterson 1985a, 1985b.

⁵⁶⁹ Hasaki 2002, p. 316.

However, with perhaps a dozen workshops active in seventh-century Corinth making decorated fine pottery, competition would pressure potters to work efficiently. Workshops that had invested in a kiln had an incentive to use it throughout the season. A potter benefited by creating a steady stream of objects to load a kiln for regular firings, giving him an incentive to variegate his production according to demand.⁵⁷⁰ After investing in the facilities and acquiring the competence in the full manufacturing process, ceramicists would benefit by diversifying when demand was too sporadic to sustain intensive, full-time production of a single type of object. Nevertheless, the differences in firing hinder crossover production of both fine and coarse pottery. Secondary specializations emerge around specific shaping techniques, such as hand forming amphoras, molding bricks in a wooden frame, or throwing pottery and lamps on the wheel. However, the examples described here indicate that the range of secondary specializations developing in a particular workshop varies unpredictably, probably because these choices depend primarily on an individual craftsman's skills and the local demand.

7.C.4) *Other modes of pottery production: amphoras and itinerant potters*

Further insight into workshop organization is found in a technical analysis of Corinthian transport amphoras developed by the beginning of the seventh century B.C.⁵⁷¹ Vandiver and Koehler analyzed surface markings and microstructure of Corinthian Type A and B amphoras, also creating experimental replica jars from clays mined in the Corinthia (Figure 7.19).⁵⁷² The Corinthian A amphora, the only transport amphora type manufactured in the seventh century, was handmade perhaps with the assistance of a tournette (a slow turntable), but it is otherwise unlike the handmade

⁵⁷⁰ Hasaki 2002, pp. 269-270.

⁵⁷¹ Koehler 1979, pp. 10-12; Whitbread 1995, p. 256-257.

⁵⁷² Vandiver and Koehler 1986.

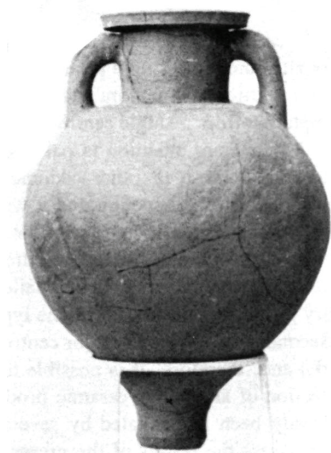


Figure 7.19 Corinthian Type A amphora (Corinth Inv. C-1977-120: Whitbread 1995, pl. 5.1)

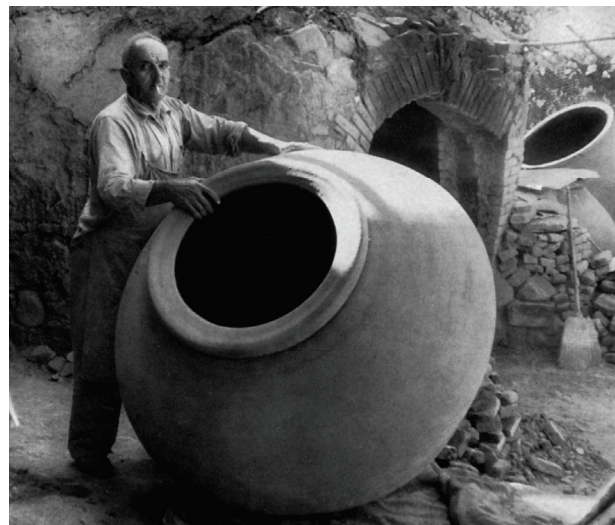


Figure 7.20 *Pithari* at Phini, Cyprus (Hampe and Winter 1962, pl. 37.1)

pottery intended for domestic use which Peacock classifies in the household or household industry modes of production.⁵⁷³ Because the clays, shapes, and manufacturing techniques were excellent for transport, Vandiver and Koehler argue instead that specialist potters tried to “optimize” the performance characteristics of the amphoras, and the lack of finish also suggests the craftsmen were producing them as quickly as possible.⁵⁷⁴ Thus, the endurance, consistency, and wide export market for these amphora types clearly locate them in Peacock’s workshop industry mode of production. Although no production site has yet been identified at Corinth, small workshops independent from the Potters’ Quarter, the Anaploga Well, and the Tile Works must have made these handmade jars.

Pithoi are another significant class to compare to tiles due to their unique construction techniques which usually require a separate workshop structure. The largest jars can weigh hundreds of kilograms and have storage capacities of several hundred or even thousands of liters. Pithos makers are often itinerant, leaving few

⁵⁷³ Kourou 1994, pp 43-47; also see above, note 395.

⁵⁷⁴ Vandiver and Koehler 1986, pp. 174, 202-205, 211-213.



Figure 7.21 Tinajas near Villarrobledo (Vossen 1972, pl. 6)

chances for archaeologists to recover their work sites. A few pithos fragments from Corinth are published, establishing the fact that they were known in the Archaic period.⁵⁷⁵ However, it is necessary to turn to ethnographic accounts to understand the production process.

The Cretan *pitharia* are the best known.⁵⁷⁶ The jars are constructed gradually on turntables over the course of a day, limiting their height to about 1.20 m and storage capacity to about 350 liters.⁵⁷⁷ The itinerant teams of six Thrapsano potters are the most famous producers, but at permanent workshops in Kentri and Margarites on Crete, Kornos in Cyprus, various workshops on Kos, and others in South Italy, *pitharia* with capacities ranging between 150 and 300 liters were thrown by a potter with only one or two assistants.⁵⁷⁸ In Guellala on Djerba, a potter with one assistant threw 300-liter storage jars in sections over the course of a month (above, Figure

⁵⁷⁵ Only a few fragments of pithoi have been published from Geometric and Protocorinthian contexts at Corinth: Pfaff 1988, p. 33. Perirrhanteria, which appear at Corinth by the Protocorinthian period, are relatively small and have a fine, untempered fabric: Iozzo 1987, pp. 355, 358-359.

⁵⁷⁶ See above, note 492.

⁵⁷⁷ Hampe and Winter 1962, pp. 19-21.

⁵⁷⁸ Cyprus: Hampe and Winter 1962, pp. 56-57; Italy: Hampe and Winter 1965, pp. 52-54, 69, 179-180 (Pisticci, San Pietro); Kos: Psaropoulou 1984, pp. 18-20, 69; Kentri: Blitzer 1984, p. 145, 151; Margarites: Hampe and Winter 1962, pp. 33-35.

7.8).⁵⁷⁹ Heavier pithoi could not be constructed on a wheel. Thick-walled and coarsely tempered with shales, the *pitharia* manufactured near Koroni were gradually built indoors by a master with one or two assistants over the course of twenty days.⁵⁸⁰ Although 250 liters was the largest size manufactured recently, in the past jars weighing 200 kg empty could hold 500 to 1,000 liters.⁵⁸¹ A potter assisted by his son created round *pitharia* in Phini on Cyprus, the largest exceeding 1,000 liters in capacity and built up over the course of two months (above, Figure 7.20).⁵⁸² When needed at another town, the pithos maker traveled to build the jar at a provisional workplace at the installation site, relying on a local brick kiln to fire it.⁵⁸³ The largest storage vessels, however, were the giant *tinajas* produced in two nucleated industries at Villarrobledo and Colmenar de Oreja in Spain.⁵⁸⁴ Most of the wine jars held 3,000 to 4,500 liters, and nineteenth-century documents describe 8,000-liter jars over 5 m high (Figure 7.21).⁵⁸⁵ Potters spent up to nine months building each jar, eventually requiring scaffolding to reach the upper walls. Although astonishingly large, even the Spanish *tinajas* were matched in size by the enormous storage urns in Minoan and Mycenaean palaces, and large pithoi continued to be manufactured through the Dark Age.⁵⁸⁶ Several pithoi installed in the Classical houses at Olynthus have price inscriptions ranging between 31 and 54 drachmas, the cheapest holding approximately 1,000 liters.⁵⁸⁷ If each potter earned one drachma per day, these prices suggest two potters may have worked together for two to four weeks to gather clay and fuel and to complete each jar.

⁵⁷⁹ Combès and Louis 1967, pp. 81-86, 89.

⁵⁸⁰ Blitzer 1990, pp. 679, 682, 685-686; Hampe and Winter 1965, pp. 47-54.

⁵⁸¹ Blitzer 1990, pp. 686-691.

⁵⁸² Hampe and Winter 1962, pp. 62-65; 1965, pp. 65-73; Ionas 2000, pp. 201-204.

⁵⁸³ London 1989, pp. 65-71.

⁵⁸⁴ Garcia Gómez 1993; Garcia Fernández 1948; Vossen 1972, pp. 27-28.

⁵⁸⁵ Garcia Fernández 1948, pp. 655-657.

⁵⁸⁶ Cullen and Keller 1990, pp. 190-197.

⁵⁸⁷ Amyx 1958, pp. 279-280; Cahill 2002, pp. 227-228; Cullen and Keller 1990, p. 198.

Pithos production follows a very different schedule from other forms of pottery. Land transportation was costly, giving pithos makers incentive to work as near to their markets as possible. However, demand is also sporadic, because pithoi can be used for decades without replacement and were needed in rural areas. Potters adopt different schedules depending on their production techniques. “Fast” producers who finish each jar within a day using turntables are distinct from “slow” producers who hand build each pithos over three weeks to several months. Fast producers such as the Margarites workshops are generally sedentary specialists in smaller types of coarse pottery who occasionally make *pitharia* which are small enough to be transported short distances over land. The Thrapsano pithos makers developed a unique strategy mixing itinerant circuits with fast production, changing locations each year to ensure a market for 500 jars nearby their chosen production site for the season. Slow producers like the workshops around Koroni usually rely on merchants to ship large *pitharia* to major ports. In order to be productive throughout the day, potters with fixed workshops would work on dozens of jars simultaneously, moving from one to the next over the course of a day. Itinerant “slow” pithos makers are not well documented ethnographically, but in Cyprus they also appear to have traveled established circuits, leaving enough time between visits for demand to build up at each site. A master pithos maker had one or two assistants to prepare clay and to move the pithoi but had no incentives to hire others. The six-person teams from Thrapsano are exceptionally large, probably due to their unusual, intense production techniques and the high demand for their *pitharia*.

Itinerant craftsmen were not true wanderers. The pithos makers in Crete had permanent workshops at their homes in Thrapsano, which they left every year for only a one-hundred-day season. Cypriot pithos makers seem to have developed a similar practice. They were based in villages with many other potters, and they left for special

commissions only because their products were too large to ship efficiently to remote customers.

Thus, pithos makers are subject to many of the same economic forces as brick and tile makers. Like brick, the bulk of a pithos makes long distance transport overland risky and uneconomical. As a result, workshops supply only a small region and are dispersed in order to keep prices low.⁵⁸⁸ Where demand is inadequate for full-time production, workshops produce other objects to survive, sacrificing efficiency. Otherwise, a larger team can maintain a more efficient, intensive production cycle by becoming itinerant. In a similar way, craftsmen who created architectural terracottas throughout the Archaic period are often hypothesized to have been itinerant or else limited to activity within one region.⁵⁸⁹

7.C.5) *Technology and skill of Corinthian potters before the origins of tiles*

To conclude, in the period before the fabrication of the first Protocorinthian roof at Corinth there would have been only two principal groups of specialist potters working in separately organized workshops: producers of fine pottery and producers of coarse pottery. Fired brick was not used, and tile production would not develop as a separate specialization until several generations after the construction of the Old Temple, when tiles become commonplace in domestic architecture. No evidence at Corinth indicates an equivalent to the mixed production of tiles, textiles, inlays, and bronze at the late seventh-century unwalled workshop at Poggio Civitate.⁵⁹⁰

⁵⁸⁸ Peacock 1979, pp. 6-7.

⁵⁸⁹ e.g., Billot 2000, p. 233; Mertens-Horn 1990; Thompson 1980, p. 18; Williams 1988, pp. 228-229; Winter 1993. However, roof tiles were shipped in the Tyrrhenian as early as the Archaic period: Lulof 2006.

⁵⁹⁰ An alternative model of “attached specialists” is perhaps indicated here: Berkin 2003, pp. 12-14. Also see above, note 274.

The context for fine-ware production may be reconstructed from the ethnographic sources, the extended analogy to Athens, and the wealth of excavation at production sites in Corinth. Given the evidence for a limited volume of production even for the highest-quality pottery in Athens, it is unlikely that any pottery production at Corinth remotely resembled the high-volume, tightly organized production characteristic of Peacock's manufactories or the Penthesileans. The longstanding characterization of Corinthian "mass production" of export pottery in "factories" is no longer viable.⁵⁹¹ The identification of the Potters' Quarter invites at least some comparison to a nucleated industry, although its configuration, which will be considered again below, is uncertain at the time of the construction of the Old Temple. The wide exportation of Corinthian pottery suggests a distribution network with ship merchants serving as middlemen, which is characteristic of a developed nucleated industry in Peacock's model. However, only about a dozen workshops seem to have been actively producing fine wares, falling short of the typical nucleated industries in the ethnographic record. Based on all the factors, Corinth had risen at least to the level of the workshop industry. As indicated by the identifiable hands of specific painters, certain craftsmen had invested enough time in vase painting to develop stereotypical decorative styles. Even if there were comparatively few fine-ware producers, their broad export market indicates these few workshops had invested in the facilities and developed the skills to throw large quantities of black gloss pottery exceeding local demand. Sales must have been vital income for these potters, whether at local markets or for export, providing an incentive to work throughout the year within the climatic constraints.⁵⁹²

⁵⁹¹ See above, note 410.

⁵⁹² Arafat and Morgan 1989, pp. 328, 341; Morgan 1995, pp. 327-332; Peacock 1982, pp. 9, 25-43. These correspond to the "individual industry," "workshop industry," "village industries" in the typology in van der Leeuw 1977, pp. 72-74.

Workshops would have invested substantially in fixed equipment such as potters' wheels and permanent kilns and in facilities such as workrooms, sheds, mixing basins, courtyards, and drying areas. Although some fine wares would have been produced within a family, the majority would be larger male-dominated enterprises of one or two potters and their assistants. There is no evidence at Corinth that potting and painting were separate roles. With only about 50 workers in the whole industry, it is unlikely that strict specialization within large workshops could have developed. It is very unlikely that individual workshops could have reached the maximum of nine or fifteen workers suggested for the larger Attic red-figure producers. Instead, three to six laborers with variable roles in the production process would have been typical in early Archaic Corinthian workshops.

Although individual workshops would have been small, the craftsmen had polyvalent skills. Specialist potters undergo years of training to become proficient at their craft. Not only could they shape a wide variety of pots, but also these potters would have been familiar with the full production process. As the material from workshops at the Potters' Quarter, the Tile Works, Phari, and Figaretto demonstrate, a wide variety of objects were produced in close proximity to one another. It is uncertain whether individual craftsmen regularly fabricated every type. However, considering the tendency for objects sharing common manufacturing techniques and fabrics to cluster in one production area, the likelihood that demand was variable or sporadic, and the small scale of the workshops, it is probable that fine-ware potters in the early Archaic period had mastered the full production sequence for a variety of objects besides just painted, wheelmade vases. A potter easily could add small wheelmade lamps to his repertoire, and he could learn to create and paint figurines with molds purchased from other workshops such as the Tile Works.

The manufacturing technologies themselves are often bypassed when discussing the role of ancient potters,⁵⁹³ but the Corinthians' competence was high in comparison to many of the ethnographically documented potters. Except for the faience makers in Fes and Nabeul, potters were producing plain pots with only minimal painted decoration. By the mid seventh century B.C., however, Corinthians had mastered a complex production sequence to acquire, levigate, and fire fine clays and paints, and they were able to throw elaborate vessel forms consistently on a high-speed turntable. They could build and fire enclosed kilns capable of sustaining a steady temperature in the range of 800 to 1,000 °C with an oxidation-reduction-oxidation firing cycle to create a sintered black gloss with added polychrome decoration (above, Figure 7.14).⁵⁹⁴ Corinthian potters did not produce the enormous funerary urns for elite burials that appeared elsewhere in the Greek world such as at the Dipylon cemetery, but they did develop the first major export market represented by very big quantities of Greek pottery. The uniformity of the small vessels invited the characterizations of "mass production" in the past, but the painted pottery was also well crafted throughout the Protocorinthian period. Corinthian producers maintained high standards over a large volume of production.

Less can be said about coarse wares. Corinthian A amphoras are distinguished from fine-ware producers by hand building, the paste, and the firing process. Too few of the amphoras remain from the first half of the seventh century to argue for a high intensity or large scale of production, and Koehler speculates that a single workshop might have created all the early amphoras.⁵⁹⁵ It is likely that no more than a few small workshops with two to four employees each were producing these and other types of

⁵⁹³ Arafat and Morgan 1989, p. 315; Crielaard 1999, p. 53, 57-58; Stissi 1999, p. 87.

⁵⁹⁴ On Attic black gloss technology see: Jones 1986, pp. 798-805; Kingery 1991; Maniatis, Aloupi, and Stalios 1993; Noble 1988, pp. 79-97, 148-165. Also see above, note 309.

⁵⁹⁵ Koehler 1979, p. 13.

utilitarian domestic pottery. It is impossible to hypothesize the organization of pithos makers without knowing more about their storage capacities and construction techniques from early Archaic Corinth, but one or several potters may have known how to build thousand-liter jars at the time. Because the heavy fabric and the hand-building techniques are similar, pithoi and smaller utilitarian domestic pottery could have been made by the same craftsmen. If there were about a dozen pottery workshops specializing in fine wares, then perhaps another dozen or fewer workshops produced coarse amphoras and pithoi.

7.D) Technology and skills of Protocorinthian tile makers

Having described the context of the ceramic industry in the seventh century B.C., we may return to the origins of the Protocorinthian roofing system. The tiles and pottery share several technical features, including the fabric, forming techniques, decoration, and scale of production.

According to Whitbread's recent petrological study of the type A and B amphoras, Corinthian amphoras were produced using a similar clay mixture to tiles.⁵⁹⁶ The fabric of several roof tiles and architectural terracottas is close to that of the Type A' amphora.⁵⁹⁷ Moreover, at least two roof tiles Whitbread examined belonged to the Old Temple roof.⁵⁹⁸ Although the Type A' amphora is dated no earlier than the fifth century B.C., the fabric of the early seventh-century Type A amphoras also is similar to the Protocorinthian tiles', and all three are tempered with crushed fragments of mudstone.⁵⁹⁹ Thus, the tile makers adopted a recipe for ceramic paste from an established tradition of coarse pottery manufacture.

⁵⁹⁶ Whitbread 1995.

⁵⁹⁷ Whitbread 1995, pp. 293-296.

⁵⁹⁸ See above, note 355.

⁵⁹⁹ Whitbread 1995, pp. 256-258, 268-278, 294-296; Whitbread 2003, p. 9.

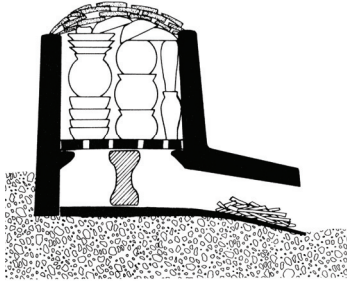


Figure 7.22 An open-topped updraft kiln (Rice 1987, fig. 5.22)



Figure 7.23 Thrapsano potters install lintel bricks to support the floor of a kiln built at Asomatos (Hampe and Winter 1962, pl. 3.1)

Protocorinthian tiles, however, were not handmade. The tile-making frame is similar to the open-topped form used for producing mud bricks, which was well known in vernacular Corinthian architecture. Whether or not they mass produced bricks for construction, potters too would have learned sophisticated brick-making techniques for building and repairing kilns. Ancient Greek kilns are built from unfired mud bricks,⁶⁰⁰ unlike modern wood-fired kilns built from refractory bricks to withstand much higher temperatures than were necessary for ancient pottery.⁶⁰¹ The ancient updraft kiln is divided into two compartments, with a firing chamber for the wares directly above the combustion chamber. During firing, heat rises through the perforated floor of the firing chamber and escapes through openings in its roof (Figure 7.22).⁶⁰² In most cases, the floor is supported by a central column in the combustion chamber, leaving an unsupported space between the column and the walls of the kiln which often exceeds one meter. The gap is spanned by specially formed, elongated

⁶⁰⁰ Hasaki 2002, pp. 71-73. For one account of the construction see: Combès and Louis 1967, pp. 62-63.

⁶⁰¹ Rhodes 1968, pp. 94-115.

⁶⁰² Hasaki 2002, pp. 77-90, 149-176.

bricks that could withstand the brunt of the flames, which could exceed 1,000 °C, without collapsing. Hampe and Winter observed as the pithos makers from Thrapsano created such bricks at Asomatos.⁶⁰³ Their round kiln with a central pillar belonged to a type that has survived essentially unchanged since the Bronze Age.⁶⁰⁴ They created narrow bricks roughly 75 cm long to support the perforated floor, filling in the gaps with smaller bricks (Figure 7.23).⁶⁰⁵ For the experimental replicas of Protocorinthian tiles at Isthmia, researchers aided by local workmen built a mud-brick kiln.⁶⁰⁶ Although they designed the roof as a barrel vault, which was not known in Archaic Greece, they also experimented with elongated bricks for a corbelled roof. They found the tensile strength of 64 x 19 x 6 cm bricks was more than enough to support a kiln load.⁶⁰⁷ Kiln builders since the Bronze Age would have been familiar with the tensile strength of elongated bricks. Lintels for the kiln floor and large Protocorinthian roof tiles are both load-bearing, elongated, fired-clay slabs, and this knowledge from kiln architecture might have facilitated the invention of the tiled roof.⁶⁰⁸

The decoration and scale of production for Protocorinthian tiles are connected to the fine-ware industry. The upper surfaces of every tile were coated with a fine slip to conceal the rough, tempered fabric. Approximately one fifth of the regular and eaves tiles is painted black.⁶⁰⁹ Although the composition of the paint has not yet been compared directly to Middle Protocorinthian fine wares, it is likely that the slip layers are similar. The paint is either matte or else crackles and develops a dull sheen, and many times it fires reddish brown in patches. The color of the dark paints on

⁶⁰³ Hampe and Winter 1962, pp. 17-18, 21-25.

⁶⁰⁴ Kiln type Ia: Hasaki 2002, pp. 154-155. Continuity in design: Hasaki 2002, pp. 178-182.

⁶⁰⁵ Hampe and Winter 1962, p. 24 figs. 20-21, plates 2-3.

⁶⁰⁶ Rostoker and Gebhard 1981, pp. 215-220.

⁶⁰⁷ Rostoker and Gebhard 1981, pp. 216-217. On difficulties from inadequate lintel bricks in the floor of an experimental kiln built at Amarna: Nicholson 1995, pp. 240-245.

⁶⁰⁸ Robinson articulated a similar hypothesis: Robinson 1986, pp. 43-44.

⁶⁰⁹ See above, note 190.

Protocorinthian pottery sometimes is imperfect as well, and potters accustomed to firing small vessels would have struggled to maintain an even reducing atmosphere in kilns designated for large roof tiles. Besides the decoration, the production of large quantities of uniform objects is familiar to specialized fine-ware potters, who are able to throw and paint thousands of standardized pots on a consistent schedule. Ceramicists faced with the challenge of creating 1,500 uniform, interlocking roof tiles would have had to modify the scheduling of the production sequence from pottery making.

Another technique adapted by potters and mud-brick makers to Protocorinthian tile making is producing objects in parallel. Potters do not complete an entire forming and finishing sequence for a single vessel at one time and then move on to the next, because they must wait for long periods between many production steps. For example, different segments of a vase must stiffen before they can be joined, and a fully shaped pot must dry leather hard before painting. Other aspects of the production sequence like mixing clay or throwing from the hump are more efficient when performed in large batches. The drying period is most significant for large pots like *pitharia* or *tinajas*, where hours or days must pass before raising the walls by another segment. Potters solve scheduling problems by working in parallel, adapting to work on many objects at once. Protocorinthian tiles are clearly formed from one mass of clay,⁶¹⁰ so the primary forming could occur relatively rapidly. However, because they are large objects constructed in open-topped frames, the tiles would need a significant time to dry. Like the eight to sixteen Cretan *pitharia* constructed simultaneously on rows of turntables (below, Figure 8.2), or the dozens built at once in workshops around Koroni, Protocorinthian tiles almost certainly were built in parallel, allowing small teams to maximize their productivity throughout the work day.

⁶¹⁰ See above, Figure 5.3.

Although a tile or fired-brick industry had not yet developed in early Archaic Corinth, a Protocorinthian tile workshop managed by potters would have resembled the temporary brickyards described by ethnographers in many ways. The team would have worked out of doors with enough space to work on many tiles in parallel and with a well-ventilated but shady drying area. Individual tiles are heavy and difficult to manipulate, so a tile former would have worked with an assistant for much of the process. A large volume of clay is needed for every tile, so one or two other workers would have been responsible for acquiring clay and kneading the tempered paste. Other tasks include manipulating tiles while they dried and managing the many kiln loads needed to fire enough pieces for the whole roof.

The minimum effective crew for accomplishing each of these jobs is no fewer than three workers. In that scenario, the minimum crew would need to change jobs frequently, shifting among preparing clay, shaping tiles, rearranging drying tiles, and firing kiln loads. Small, part-time producers of bricks and tiles with only two or three craftsmen often work in this manner. The roof of a monumental temple, however, created a one-time demand for more than 1,500 complex tiles, and a larger crew could have completed the job more quickly. At least as many craftsmen would have been recruited for such a big project as were found in the full-time pottery workshops. A crew of at least five or six workers—about the size of a contemporary Corinthian fine-ware workshop or the standard crew of a brickyard—would likely have worked full time to fabricate the first Protocorinthian roof. Considering their familiarity with the performance characteristics of local clays and their knowledge of a variety of production techniques, experienced potters and their apprentices would have been recruited for the team. Due to their technical features shared with all varieties of Corinthian pottery, Protocorinthian tiles would have been created by craftsmen from both fine and coarse ware workshops.

CHAPTER 8: THE COST OF THE OLD TEMPLE ROOF

How was labor organized to create the first Protocorinthian roof at Corinth? The production sequence must be broken down into smaller components to find an answer, following the broad outlines of the previous chapters. First, a general hypothesis for the forming and finishing sequence was formed. The hypothesis was refined by comparison to replication experiments, ethnographic studies of tile and brick makers, and the markings on the ancient tiles. The technology, production organization, and mineral resources of the ceramics industry in seventh-century Corinth were analyzed in the same manner. All of these approaches may be synthesized into a single model of a minimum effective crew and the cost in man-hours to fabricate and deliver the entire roof.

The combined model separates Protocorinthian tile production into several distinct components. First, the location of the worksite is treated as an ecological problem. Second, the time required for shaping each tile is reconstructed from the replication data. Third, after establishing a base rate for tile production, the labor necessary to prepare optimal paste is estimated using ethnographic parallels. Fourth, the work for mining and transporting raw materials to the worksite to match the rate of tile production is established. The final proposal is a schedule for firing kilns and delivering tiles to Temple Hill. The resulting cost estimate is a realistic minimum attainable by a small crew of skilled craftsmen. The probable schedule of labor can be integrated into the seasonal calendar for Mediterranean pot and tile making.

8.A.1) *Location of the raw materials*

The first problem to consider is determining the source for raw materials. There is little debate about the source for the temper in Protocorinthian tiles because

the closest prominent exposures of mudstone are on the western slopes of Acrocorinth and the ridge of Penteskouphia castle (above, Figure 6.1).⁶¹¹ As already discussed, sources for clay in the region are more diverse. The experimenters who produced replicas of Protocorinthian tiles at Isthmia mined their clays from Solomos, where modern brickyards developed around a good source. Although the clay was suitable for the task, later tests indicated that its composition does not closely match ancient Corinthian ceramics. The Isthmia experimenters explored no alternative sources and did not consider the cost of overland transportation of raw materials from Solomos to the construction site.⁶¹² In order to reconstruct the ceramic ecology of the Corinthia more effectively, there are two principal sources of information: ethnographic models for clay procurement, and the material properties of Corinthian clays.

Distance to resources is a significant constraint for pottery producers. Arnold developed an exploitable threshold model for potters who did not use industrial facilities and could not afford to transport clays by car.⁶¹³ In his cross-cultural ethnographic survey, about 90% of potters obtained clays within 7 km of the workshop, the exploitable territory threshold. It is unusual for ceramic production to occur farther than this distance from good clays, and cultural factors are offered for the cases where potters travel farther from their workshops. For example, in a study of the female domestic potters of the Shipibo-Conibo in the Amazon, potters traveled longer distances to clay sources than necessary due to other business, such as visiting kin.⁶¹⁴

The ceramic exploitable-territory model can incorporate a more nuanced definition of distance than the 7-km radius from a workshop. Transport costs can also be represented by energy expenditure; the social costs of separation from the

⁶¹¹ See above, note 316.

⁶¹² See below, note 667.

⁶¹³ See above, note 49.

⁶¹⁴ DeBoer 1984, pp. 542-549.

community entailed by long-distance travel; and the “pheric distance,” the time necessary to traverse the topography.⁶¹⁵ Within a range of 7 km, ancient potters would have remained inside the political territory of the Corinthia. The pheric distance to resources is relevant to the mountainous topography of the Corinthia.

Of course, clay is not the only factor for situating workshops. Mediterranean potters will choose a worksite with good access to water, fuel, and markets even if they must travel farther to clay deposits.⁶¹⁶ Clay is generally more plentiful than fuel, and it can be transported to a site more easily than water. Fuel must be gathered from an extensive area, and potters usually rely on agricultural byproducts in their regions to keep down the cost of firing kilns.

Tile and brick makers in particular are constrained by pheric distance to clay sources because more than one m³ of paste must be extracted and transported to the work site every day.⁶¹⁷ With 1,491 Protocorinthian tiles weighing approximately 31 kg each, more than 46 tons of raw material must be transported to the worksite over the course of the job.⁶¹⁸ All of the areas for mining clays discussed in Chapter 6 are within a radius of 5 km from Temple Hill, and the western sources analyzed by Whitbread are all within 3 km of the Potters’ Quarter (above, Figure 6.1). No source can be eliminated on the basis of the exploitable territory threshold for potters, but as will be demonstrated more precisely below, the transportation cost for a tile-making worksite more than two kilometers from the primary source of clay is prohibitive (below, Table 8.3).

Water would have been a less significant problem because relatively little is needed for mixing the tile paste. There should have been many access points to

⁶¹⁵ Arnold 1985, pp. 32-35; 2005; Browman 1976. On transport costs as pheric distance, also see: Drennan 1984; Reyman and Dirks 1985.

⁶¹⁶ e.g., Hampe and Winter 1962, p. 87; 1965, p. 177.

⁶¹⁷ See above, note 272.

⁶¹⁸ See the discussion in Chapter 3.

groundwater at springs and wells in the conglomerate and marl terraces running east-west from the settlement (above, Figure 6.1).⁶¹⁹ Ancient springs are present near the Potters' Quarter and Acrocorinth, although none have yet been identified by the Tile Works to the east. The ancient water resources near the Agios Antonios, Aetopetra, and Agios Demetrios deposits are not certain, but the former two clays are mined from the banks of a deep ravine incised by a seasonally active stream. To the south, the village of Penteskouphia lies at the head of the ravine, indicating that enough water to supply several houses was present recently.

The amount of fuel needed for the full roof, however, is relatively high, and a rural site would be closer to fields for gathering wood and brush. The Archaic pottery workshops at the Potters' Quarter, at the Tile Works, and near the Anaploga well are all on the periphery of the ancient settlement. Furthermore, if the Penteskouphia plaques can be interpreted as evidence for pottery workshops in the vicinity, their findspot indicates production 3 km to the west of the primary settlement.

However, the worksite for Protocorinthian tiles should have been in a temporary, open area, rather than inside an existing pottery workshop. The substantial area for shaping and drying tiles both in direct sunlight and in the shade is much larger than traditional pottery studios. The proximity to raw materials and the Temple Hill construction site would have been important factors. A large kiln is the only major installation needed at the site. In general, a rural site near a good clay deposit and a reliable source for water are required.

8.A.2) Constraints for locating the Protocorinthian worksite

In order to calculate the transportation cost of the roof, it is necessary to select a specific worksite. The following table compares the four clay sites exploited during

⁶¹⁹ Landon 2003, pp. 43-44, 47 figure 3.1, 54-55, with bibliography pp. 58-60.

the replication experiments (Table 8.1). The amount of dry clay and water needed to produce 100 liters of fired fabric with 25% tempering are presented along with the distance to the Potters' Quarter, an approximate waypoint between each site and Temple Hill.

The Agios Antonios clays have a slight advantage over the others. After compensating for drying shrinkage, these clays are also the lightest for mining and transporting, weighing 10% less than the Agios Demetrios clays. Based on volume, however, the best three sites are almost the same. Agios Antonios requires 23% less material than the Agios Demetrios. Water is a significant disadvantage for the Acrocorinth clays. They require 20% more water than the clays from Agios Antonios.

Acrocorinth is costly by pheric distance due to its elevation, which is between 110 and 255 m higher than the other sites. Although mudstone is available nearby the Acrocorinth clays, this is an advantage only if a worksite with adequate access to water is also located there. Other places for recovering mudstone to the west are close to the Agios Antonios chapel. Mudstone, however, is of relatively minor importance to the location of the worksite because it represents less than one fifth of the total volume and weight of the raw materials. Finally, the distance to the Potters' Quarter is important only for the final transportation costs. The Agios Demetrios clays are closest to Temple Hill, and the Aetopetra clays have the next best location and elevation. As will be demonstrated below, however, the cost of the final transport to Temple Hill may be reduced significantly by using ox carts on established tracks.

Table 8.1 Materials required to produce 100 liters of fired tile fabric

Site	Paste	Dry clay	Water	Site el.	Distance to PQ
Acrocorinth	117 L	115 L / 148 kg	58 L	340 m	1.5 km
Aetopetra	115 L	~115 L / ~145 kg	~50 L	85-120 m	2.6 km
Ag. Antonios	114 L	114 L / 141 kg	48 L	230 m	3.0 km
Ag. Demetrios	114 L	140 L / 157 kg	50 L	200 m	0.5-2.5 km
Mudstone	n/a	25 L / 31.2 kg	n/a	290-320 m	1.1 km

The Agios Antonios and Aetopetra clays had the best workability during the replication experiments. The outcrops are cleaner than the Acrocorinth or Agios Demetrios sites, saving time for removing impurities. The clays require the least effort to extract by volume. Both outcrops and the findspot of the Penteskouphia plaques are in the same ravine, perhaps the location of Archaic workshops with kilns and an established water supply. They are also close to the lignite clay beds in the Nikoleta quarry, which is favored by Koehler, Vandiver, and Whitbread as a potential location for the clay deposits in Corinthian Type A amphoras.⁶²⁰

This survey admittedly is incomplete, lacking, for example, recipes for the usable clays to the east of the settlement near the Tile Works. However, the Agios Antonios and Aetopetra sites are the best candidates identified so far for creating the roof with the least effort.

Ancient potters may have been aware of these deposits and selected a nearby worksite with access to water. As today, the area seems to have been rural and, consequently, would have lain near sources for firewood. Although they would not have measured the volumes and weights of materials as precisely as during the replication experiments, ancient potters would have been very familiar with the properties of the clays in the Corinthia. They too would have selected a suitable deposit known from decades or even centuries of practical experience.

Because the Agios Antonios and Aetopetra clays are equally suited to the job, some performance characteristics of the two are averaged in the calculations which follow. The fired fabric is assumed to have 25% mudstone tempering, a 1.74 kg/L bulk density, and a total linear shrinkage of 4.2%. Because the recipes for the Aetopetra site are estimated, the amounts and weights of only the Agios Antonios clays are adopted from now on.

⁶²⁰ See above, notes 323 and 325.

8.B) Manufacturing Protocorinthian tiles

The time to produce regular tiles can be estimated accurately from the replication experiments. The base rate for shaping the tiles is established first by ignoring (1) the supply of raw materials to the worksite, (2) the mixing of paste, (3) the equipment and drying spaces, and (4) the firing. These additional requirements will be addressed after the maximum production rate is established.

As described in Chapter 4, brick and tile formers often work alone or in pairs. Protocorinthian tiles are so large that a former would have worked with an assistant. The replication experiments have demonstrated that a second craftsman could significantly accelerate the production process. Figure 8.1, below, shows the minimum time to fabricate one tile by both a craftsman working alone and with an assistant. These timings are optimal, equaling or slightly faster than the best time for each production step during the replication experiments (above, Table 6.6).

It is possible for one craftsman working alone to create a tile while it rests on the base mold, although lifting the tile to cut the cover rabbet is difficult without an assistant. If the former had an assistant throughout the process, the total production time is cut from 34 to 22 minutes per tile. In strict terms, this is a less efficient system than working alone, because the two craftsmen do not halve the production time by cooperating. However, it is difficult to imagine that one craftsman working alone could actually form tiles every 26 minutes without any interruptions. Minor problems that arise could be managed by an assistant instead without significantly slowing production. A third worker would likely decrease efficiency without conferring any similar advantage.

In the ethnographic documentation, an assistant often acts as a porter in addition to playing a small part of the forming sequence. He could fetch tools and materials in preparation for upcoming tasks, which would allow the former to work

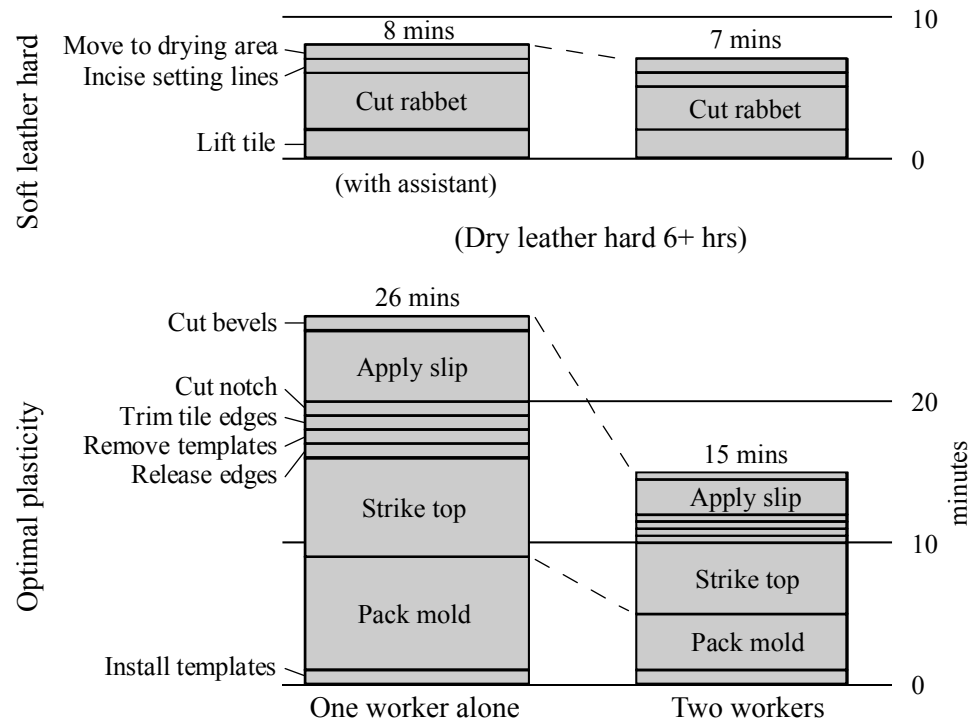


Figure 8.1 Time for workers alone or in pairs to produce a regular tile

continuously. The former is responsible for the most difficult production steps, such as striking the top of the tile and polishing slip, while the assistant might be a less-skilled worker or an apprentice. Consequently, even if the production time is not halved by adding a second craftsman, the master-assistant team is the most plausible and efficient arrangement because the less-skilled assistant leverages the productivity of the highly skilled tile former.⁶²¹

Drawing from an unlimited supply of paste and equipment, such a team is capable of producing a tile in just 22 minutes, with 15 minutes of work to form each tile before leaving it to dry for six or more hours on its base mold. Over an 11-hour work day, two craftsmen theoretically are able to create 30 tiles. Each tile must remain on the base mold for much longer than 22 minutes before it dries, so many molds are

⁶²¹ Craftsmen may have developed more complicated systems where three or more workers participated in the forming sequence. Regardless how many were involved, however, it is unlikely that more than two individuals worked on a tile at once. For example, three craftsmen constructed the Thrapsano *pitharia*, but only one or two of them executed each production step: Voyatzoglou 1984, pp. 136-139.



Figure 8.2 *Pithari*-production in parallel by Thrapsano potters at Asomatos (Hampe and Winter 1962, pl. 13.2)

necessary. After shaping one tile in 15 minutes, the team could produce 24 more before the first had dried even on hot, breezy days. Thus, like large storage jar makers, who often have dozens of jars in production at one time, the Protocorinthian tile makers almost certainly would have manufactured tiles in parallel on dozens of base molds.

The parallel production of the tiles would have closely resembled the outdoor sites of the *pithari*-makers from Thrapsano, who produced 8 to 16 jars simultaneously on as many outdoor turntables (Figure 8.2).⁶²² However, the rhythm of tile making is different because the entirety of the tile is built up at once, unlike the incremental construction of the storage jars over the course of a day.

The schedule must compensate for a long drying period before the underside can be finished. Between 5 am and 12:30 pm, the team could shape as many as 30

⁶²² Hampe and Winter 1962, pp. 17; Voyatzoglou 1973, p. 14; 1947, p. 19; 1984, p. 138; Xanthoudides 1927, p. 124.

tiles. The first would have dried sufficiently to remove from its base mold by noon. After a break, the team could start raising the tiles from the early morning, cut the cover rabbets, and move them to the drying area. They would have difficulty as the afternoon progressed, because only one third of the time is necessary to finish a leather-hard tile. The tile formers could postpone their work until late in the afternoon, and they would have alternatives for humid days. Even if some tiles have not stiffened by evening, the tile makers could have used the unoccupied molds from the ones which had dried to produce a few new tiles. Thus, by staggering production, it would have been possible for craftsmen to manufacture 30 tiles each day with an unlimited supply of clay. In actuality, it is unlikely they could maintain this speed continuously. Over the 10- to 12-hour work day typical in the ethnographic record, an average daily quota of 25 tiles allows for the loss of a few tiles each day to cracking and unexpected interruptions.

In this scenario, the two craftsmen need 30 base molds, so the worksite must extend over a large area. Each mold is more than 75 cm square on its exterior, and a gap of at least 70 cm must be left unoccupied around all sides of the mold for two craftsmen to use it effectively without bumping into adjacent molds. Arranged in a 3 x 10 grid, the 30 molds would have occupied 3.7 x 13.8 m, or 51 m². An equally large area may have been reserved for drying the tiles. Although drying tiles can be stacked on end to occupy less space, several days may pass before they are ready for loading in the kiln. An area of more than 150 m² should have been dedicated to shaping and drying tiles, not including space for clay, water, fuel, and kilns. A shady worksite is preferable in order to control drying. The unwallled workshop at Poggio Civitate invites comparison. With a total roofed area of approximately 336 m², at least half of space appears to have been dedicated to tile production at the time of its destruction.⁶²³

⁶²³ See above, note 274.

The equipment requirements are modest. Although there would have been 30 separate clay base molds, the tile makers need only one wood template frame. The frame is necessary only while the tile is formed and can be moved from one base mold to the next. The team needs only a few other shaping tools. The master uses one strike and a ruler, and both workers are equipped with a knife and spatula. The clay base molds themselves are formed in the same manner as the tiles, so it is conceivable that they were produced in just one or two days. Unfired molds would have been ready to use in just three or four days, but these may have worn out frequently during intensive tile production. If fired, all of the molds could have been ready in less than two weeks.

8.B.1) Mixing clay during the production cycle

To produce 25 tiles a day, the two craftsmen must be supported by others who prepare paste and fire tiles. Assuming a 4.2% linear shrinkage, a total of 21 liters of optimal-plasticity paste is consumed in each tile, adding up to 525 liters of paste every day of production. With 0.3 liters of slip for each tile, an additional 7.5 liters is necessary.

During the replication experiments, one worker could produce enough paste for one tile in as little as 26 minutes on site (above, Table 6.5). Although the work is tiring, it is conceivable that one specialist could prepare enough paste for 25 tiles in an 11-hour day. However, the paste of the replica tile appears inadequately kneaded, and it is unlikely that a different method was used in antiquity. Because the replication experiments only dealt with small quantities of paste, they did not simulate the traditional method of treading clay.

Before the introduction of mechanical mixers, almost all large-scale Mediterranean producers trod clay. Several ethnographic descriptions from Greece,



Figure 8.3 (*left*) Circular “dance” on the clay, (*right*) into a conical mound, Nabeul (Lisse and Louis 1956, p. 33 fig. 9 and p. 32 fig. 11, respectively)

Italy, and North Africa are representative.⁶²⁴ As in the experimental procedure, clay is mined with a pickaxe and transported in baskets to the workshop. Potters spread the dry clay on a plastered or packed-earth floor and beat down the nodules with a stick. At this time, they would sieve the clay if they needed to remove small stones. Clays are mixed with water in a basin or a pit, where they might be left to soak between one hour and two weeks depending on the clay body.⁶²⁵ When ready, the potters spread a layer of dry clay powder or ash on the floor and pile up a heap of clay from the basin. At this point, the treading commences. Keeping his feet pointed toward the center of the mass or else its exterior, the potter steps slowly around the mound for several circuits (Figure 8.3, left). Ethnographers often liken the rhythmic motion to a dance. The potter uses his full weight to stir the clay throughout the mound, softening it to a uniform consistency. After one or two hours of treading, the potter shapes it into a tall

⁶²⁴ Bel 1918, pp. 49-50; Blitzer 1990, pp. 680-683; Cintas 1949, pp. 27-28; Combés and Louis 1967, pp. 40-42; Hampe and Winter 1962, pp. 27-28; 1965, pp. 5-6, 27, 49, 87-88, 133, 178; Lisse and Louis 1956, pp. 27-35; Psaropoulou 1984, p. 16; Voyatzoglou 1974, pp. 19-20.

⁶²⁵ Large, coarse vessels and tiles were not left to soak for long, e.g.: Hampe and Winter 1965, p. 178 (one or two hours); whereas fine clays at Nabeul were soaked 15 days: Cintas 1949, p. 27.



Figure 8.4 Attic black-figure skyphos (Cambridge, MA, Sackler Museum 1960.321: Xatzedemetriou 2005, pl. 12 K41)

cone (Figure 8.3, right). This stockpile is usually wedged further by hand for large wheelmade pots or fine wares, but it is used directly for coarse objects like tiles. Two Attic black-figure cups depict potters treading similar conical mounds, suggesting the procedure has changed little since antiquity (Figure 8.4).⁶²⁶

A truncated sequence is reported for manufacturing some big pots and bricks. To manufacture the *pitharia*, the Thrapsano team's clay worker beat clay and temper on the floor of a temporary hut. Early the next morning at about 4:30 am, the potters poured water into a depression in the mound of dry clay and immediately began treading.⁶²⁷ Three or four potters worked together, building up the clay into a large

⁶²⁶ Fogg Art Museum 1960.321: Eisman and Turnbull 1978; Scheibler 1986, pp. 790-794; Xatzedemetriou 2005, p. 210 (K41). Another has been recently identified from fragments in Thasos: Maffre 1999.

⁶²⁷ Hampe and Winter 1962, pp. 27-28; Voyatzoglou 1984, pp. 132-134.

cone at the end by about 6:00 am. They kept the paste in the shaded hut and had finished it by the end of the day for the jars. The Tunisian producers of large storage jars at Guellala piled fresh clay from the mines into basins at the workshop, added water, and immediately trod the clay by foot directly in the basins.⁶²⁸ The next day the clay was piled inside the workshop and trodden in a heap using the standard technique. Thus, the time soaking the clay is reduced at Guellala by treading it in the basins, although the total labor is greater. An alternative method for mixing a tempered paste was employed until recently by some *pithari*-makers around Koroni.⁶²⁹ In these villages, clay and water were poured into a spherical container and stirred for several hours to develop a slip. The potter added crushed fragments of *lepidi*—a mixture of shale, mudstone, and chert similar to the Protocorinthian mudstone temper. The mixture was shaped into thin patties laid out to dry in the sun on hemp mats and soon transferred to a shaded stockpile to retain its moisture. The clay was never wedged, instead maintaining a soft, creamy texture preferred for constructing the rings of the *pitharia*.

Fired-brick and tile makers prepare their clays with comparatively little labor. For example, at Fes, one worker mined clay by himself from a site less than 400 m away and transported it with a donkey to the brickyard.⁶³⁰ He dumped the clay into basins and added water, leaving the clay to soak overnight. Once the clay had softened, he entered the pit to tread it. Water was drawn in buckets out of a canal cut from the adjacent river to the worksite, or else another worker with a donkey delivered water when needed. The worker responsible for forming bricks later piled the clay at the side of the basins, leaving it to stiffen in the sun. He molded bricks directly from this clay without wedging it further.

⁶²⁸ Combés and Louis 1967, p. 41.

⁶²⁹ Blitzer 1990, pp. 682-683; Matson 1972, pp. 213-214.

⁶³⁰ Bel 1918, pp. 42-43, 49-50.

Protocorinthian tile fabric was likely processed using similar methods. The even consistency and the lack of air pockets indicate the paste probably had been wedged more than the brick clays at Fes. However, no tile makers take the time to wedge their clays by hand. The rapid foot-treading procedure of the Thrapsano potters is the method that appears best suited to the large volume of paste needed for every Protocorinthian tile.

The rates for treading clay are difficult to obtain from ethnographic accounts, but several have been calculated in Table 8.2 for places where potters prepare large quantities of clay at one time.

The Thrapsano potters have the slowest rate of paste production per potter at 47-62 liters of paste an hour. However, unlike the Nabeul and Ballâs potters, they do not hand wedge their clays at all, so the Thrapsano potters may have trodden their clay more thoroughly. At Ballâs, an assistant leads two water buffaloes around the basin when a large quantity of clay is first mixed with water. Later two apprentices move the

Table 8.2 Paste preparation rates by foot treading

Site	Clay	Crew	L/man/hr	Notes
Thrapsano: <i>pitharia</i> ⁶³¹	600 kg/1.5 hr	3-4	47-62	ca. 280 L of clay
Nabeul: throwing ⁶³²	500 L/3-5 hr	1	100-170	Excluding hand-wedging
Ballâs: water jars ⁶³³	2,500 L/6hr	2-4	105-200	Also used buffaloes
Roman fired bricks ⁶³⁴	1.25-1.38 m ³ /day	< 1	> 125-140	
Fes: fired bricks ⁶³⁵	1,500 L/9 hr	< 1	> 170	Including clay mining
Surrey: bricks ⁶³⁶	1.95-5.84 m ³ /day	1	195-580	
Corinth experiments	21 L/0.5 hr	1	42	Small batches; not trodden

⁶³¹ A bulk density of 2.15 kg/L is assumed to convert 600 kg to 280 L of clay.

⁶³² i.e., one apprentice treads a pile of clay for about 2-3 hours: Cintas 1949, p. 28 note 92. The size of the clay pile is about 0.5 m³ of clay: Lisse and Louis 1956, pp. 31, 32 figures 9-12. The clay has been wetted in basins previously.

⁶³³ i.e., one mixing pit 2.5-3 m in diameter and 0.5 m deep (about 2.5-3.5 m³) is trodden by two buffaloes and later two apprentices: Nicholson and Patterson 1985b, pp. 225-227.

⁶³⁴ See above, notes 265, 272, and DeLaine 1997, p. 116 note 65. Note that Warry 2006, p. 121 figure 8.3 assigns 3.5 workers preparing clay for every tegula former, although this may be too high.

⁶³⁵ i.e., about 1500 bricks are produced in a 9-hour workday: Bel 1918, pp. 47-53. Each brick is 13 x 26 cm; with an average thickness of 3 cm, the bricks equal 1.521 m³ of paste.

⁶³⁶ i.e., from 1000-3000 bricks for one to three workers: above, notes 253-256.

clay indoors and tread it themselves for two hours, and the clay is quickly wedged by hand before throwing on the wheel.

As expected, the rate of production is faster for brick makers. The daily consumption of 525 liters (0.53 m³) of paste for tile making is low compared to bricks or Roman tegulae, where more than one m³ of paste is formed each day. The rate estimated for Roman fired bricks by DeLaine is based on the volume of bricks shaped every day, but the number of hours invested in clay preparation is unclear. The English brick-making records from 1693 suggest that brick paste could be prepared much faster than potting clays. Better documentation is available for the brickyard at Fes, where one full-time specialist mined, transported, and trod 1,500 liters of clay in a day.

Overall, it appears that one apprentice could finish treading at least 50 liters of paste in an hour. If he worked continuously for 10 hours a day, he could prepare enough for all 25 tiles, although this activity is probably too strenuous to maintain by an individual worker. However, the treading may have been significantly faster based on some of the ethnographic documentation. If the apprentice instead prepared slightly more than 100 liters per hour, he could finish a days' worth of clay in 5 hours. He would need additional time to beat and wet the raw materials, which the replication experiments suggest would require about 7-10 additional minutes per tile (above, Table 6.5). Even if the process could be streamlined by mixing several hundred liters at one time, at least two or three hours of labor is necessary before treading the paste for 25 tiles. Without precise timings, one hour is sufficient to mix 7.5 liters of slip. Yet another hour may have been necessary for preparing and applying the small quantity of black paint for one fifth of the tiles.

In conclusion, the raw materials for a daily quota of tiles can be prepared in 4-5 hours, with another 5-10 hours for treading paste. Although it is conceivable that a

single apprentice could perform all these tasks alone throughout a work day, such work is tiring. If the clay was trodden in just 5 hours, the assistant to the tile former could have swapped positions with the clay mixer periodically to distribute the work load more evenly, which would keep the crew to just three workers. However, if treading took 10 hours, a fourth worker would be necessary to keep up with the tile formers. With a crew of four, the two clay mixers would have an additional 7-13 hours between them to perform other tasks.

8.B.2) Transporting materials to the worksite

The team in this scenario must acquire raw material and carry it to the worksite. To make 25 tiles, workers must mine about 510 liters of dry clay which weighs 630 kg and 112 liters of mudstone which weighs 140 kg. They must add 215 liters of water to the paste.

During the replication experiments, mudstone was relatively easy to acquire from the Acrocorinth outcrops because weathering splinters it into tiny fragments. The most time-consuming activity is sifting out 2-4 mm particles from the others. Beating the larger fragments of mudstone is slow and tiring, and there is relatively little return on the additional effort. By sifting at the mine instead of at the worksite, mudstone particles of the desired size can be acquired about twice as quickly. Under ideal conditions, a worker can recover about 5 liters of mudstone in 4 minutes (above, Table 6.5), so the daily quota for 25 tiles is sifted at the site in about 90 minutes.

On the other hand, compacted clay is more difficult to pick from the ground but does not require any sifting on site. Clay was mined at close to 200 L/hr during the replication experiments, with one worker picking and the other filling baskets. The extraction rates for clays are seldom reported in the ethnographic record, but an exception is the storage jar industry at Guellala on Djerba. Two miners, a pickman,

and a porter cut clay from deep underground galleries and loaded baskets on camels. Over four or five hours, they had accumulated 1,200-2,000 liters of material for an average extraction rate of 300 to 400 L/hr.⁶³⁷ Thus, two workers should be able to mine 510 liters of dry clay in about 90 minutes at an intermediate extraction rate. This is a conservative estimate which compensates for compact, resistant clay deposits and loading times. A modern experiment in Sonora, Mexico, timed a single digger filling canisters with loose earth. With a shovel, the digger could sustain an extraction rate of more than 1,400 L/hour, and with only a digging stick, a worker still obtained more than 500 L/hr.⁶³⁸

Although camels have never been pack animals in Greece, potters very often use donkeys for carrying clay, water, and finished wares to and from the workshop. Ethnographers have frequently described clay transportation by donkey in Greece, Cyprus, Italy, Spain, North Africa, and Pakistan. Estimates for the maximum load of a donkey vary between 80 and 100 kg.⁶³⁹ Human porters can carry 70-100 kg loads,⁶⁴⁰ but they cannot travel as quickly or as far as a donkey. A typical nineteenth-century Englishman was able to carry 40 kg for a 20 km march at an average speed of 2.7 km/hr, whereas a donkey is able to travel 24-30 km in a day with its full load.⁶⁴¹

The ethnoarchaeological experiments from Sonora are again relevant. To estimate the manpower invested in the substructure of the Maya pyramids in the Yucatan, Erasmus timed two Mayo native Americans carrying earth in containers over distances of 50 and 100 m. They worked in the full sun for 6 hours starting at 6:30 am.

⁶³⁷ i.e., the miners load 6-10 camels with 5 baskets of 40 L on each camel: Combès and Louis 1967, pp. 37-39.

⁶³⁸ Erasmus 1965, p. 285.

⁶³⁹ Cotterell and Kamminga 1990, p. 194 table 8.1; Rye and Evans 1976, pp. 75, 119; Vossen 1984, p. 365.

⁶⁴⁰ Cotterell and Kamminga 1990, p. 193; Drennan 1984, p. 105; Reyman and Dirks 1985, pp. 889-890; Rye and Evans 1976, pp. 75, 119.

⁶⁴¹ Cotterell and Kamminga 1990, p. 194.

By 11:30, the temperature had risen above 43 °C, and the workers slowed enough that timing was halted at 12:30 pm.⁶⁴² The worker who traveled 100 m walked slightly faster than the other probably because he made fewer than 60% of the trips of the worker moving earth over the shorter distance of 50 m, thereby wasting less time emptying his canister on the dirt pile. In 5 hours, the faster worker averaged 4.6 km/hr, and, in the fifth hour of the experiment, he still traveled at 4.0 km/hr.⁶⁴³ He traversed 26.8 km in six hours, half of the time bearing a canister with about 20 kg of earth. Because the ancient Maya had no pack animals equivalent to the donkey, only Mayo natives were tested as porters in the Sonora experiments.

In light of the Mayo laborers and the expectations for Englishmen in a cooler climate, it is reasonable to propose that ancient Corinthian miners could sustain the transport of about 30 kg of raw materials as far as 20 km in a day. With the workshop sited near the clay source rather than the mudstone deposit, the majority of the travel would involve little change in elevation. An average walking speed of 4.0 km/hr is plausible as long as the total distance is limited.⁶⁴⁴ It is very likely that pack animals would have been used as well. Almost all of the large-scale producers in the Mediterranean moved clay to their workshops on donkeys or camels, and even relatively small-scale potters in Pakistani villages used donkeys to extract clays from sources as near as 150 m from the workshop.⁶⁴⁵ The donkey would have been the default pack animal for potters of ancient Corinth as well, although mules are another

⁶⁴² Erasmus 1965, pp. 283-285.

⁶⁴³ i.e., 134 trips for a total of 26.8 km in 6 hours; in the fifth hour, the worker made 20 trips for a total of 4.0 km: Erasmus 1965, p. 284 and 284 table 1.

⁶⁴⁴ This also conforms to the expectations for energy expenditure. An unladen walking speed greater than 6 km/hr falls under the 'moderate' work rate typical for builders, and efficiency drops slightly with loads greater than 15 kg: Durnin and Passmore 1967, pp. 42, 47, 62-64.

⁶⁴⁵ Rye and Evans 1976, pp. 20 (2 km), 28 (2 km), 31 ("nearby"), 37 (4.5 km), 39 (5 km), 45 (150 m), 50. Only one potter carried his clay by himself from a site 150 m away from the workshop: Rye and Evans 1976, p. 10.

Table 8.3 Hours to retrieve clay and mudstone for 25 tiles

dist. to clay	miners / donkeys (converted to hours / distance for 770 kg raw material)					
	1m / 0d	2m / 0d	1m / 1d	2m / 1d	1m / 2d	2m / 2d
100 m	12h/23km	5.7h/11km	6.9h/5.3km	3.9h/4.3km	6.4h/3km	3.5h/2.6km
250 m	13h/29km	6.5h/15km	7.3h/6.7km	4.2h/5.5km	6.6h/3.8km	3.7h/3.4km
1,000 m	21h/61km	10h/30km	9.1h/14km	5.7h/11km	7.6h/7.9km	4.6h/7km
2,500 m	37h/124km	19h/62km	13h/29km	8.6h/23km	9.7h/16km	6.4h/14km

*Mudstone source 2,000 m from worksite, travel 4.0 km/hr,
clay mined 170 L/hr/worker, mudstone sieved 75 L/hr/worker*

possibility.⁶⁴⁶ Keeping a donkey not only allows the miners to pass the day more pleasantly, but also it improves efficiency when an average of more than 770 kg of material is transferred each day.

The problem has too many variables to solve for a single optimal solution, but the possibilities may be narrowed. Assuming a mudstone source 2.0 km from the worksite and the extraction rates, carrying capacities, and walking speeds described above, the number of hours to acquire and deliver enough material for 25 tiles is presented in Table 8.3.

Two workers take about 3 hours to mine and sift 770 kg of clay and mudstone, and one miner takes twice as long. The remaining times in the table are expended on transportation. Mining is hard labor, so the additional work of traveling to and from the mines, half of the time with a 30-kg load, should be minimized. All of the configurations where miners must travel farther than 20 km are untenable and have been shaded dark in the table. Other configurations are possible, but less favorable, because more than 10 km of travel are required per day or the relative efficiency is low. These are lightly shaded. In no case can a single miner working alone meet the daily demand under the assumptions.

⁶⁴⁶ Griffith 2006, pp. 224-228, 233-241. Because they must be carefully bred, mules are of higher value and would have been less commonly available. Only donkeys are considered in the following calculations.

The table emphasizes the importance of proximity to clays. Transportation times and total distances are high when the resources are 2,500 m away from the worksite. Only with two donkeys would it be possible to gather enough materials without exceeding 11 hours or 20 km per day. At a kilometer's distance to clay, the demand can be met with a single donkey, but it would be advantageous to use a second donkey to reduce the daily travel distance by 4-6 km. For clays within 250 m of the worksite, one donkey is more efficient than two. By adding the second donkey, the total extraction time is reduced by only a half hour per day (less than 14%), and, at best, the total distance is reduced only from 6.7 to 3.8 km. Neither distance is especially taxing for the workers. The optimal solution is for one miner to gather raw materials with one donkey, which is about 14% more efficient for time than two miners with one donkey.

The system may be integrated with the team at the worksite. Taking the conservative estimate for the rate of treading paste, four craftsmen are already at the site, two forming tiles and two preparing paste. During an 11-hour day, the two clay workers have at least 7 hours free between them, so they could share most of the 6.9 to 7.3 hours of mining in the optimal solution. With a rate of 55 instead of 50 L/hr for treading paste, these two craftsmen would have 7.3 hours free for mining clay. Thus, as long as clay deposits were within a radius of about 250 m from the worksite, two clay workers could have shared the jobs of extracting materials and preparing paste.

The last resource is 215 liters of water for each day of production. Only the cost of delivering this water to the worksite must be considered, because the time for adding water to the paste has already been incorporated into the model. If the worksite is near a spring, the work might be accomplished by gravity alone as long as a steady flow of 0.15 liters per minute arrives at a cistern on the site. In modern workshops without plumbing, water is often delivered in jars on pack animals. By himself, one

worker could fill and carry back 31-liter jars of water to the site in seven trips, but with a donkey only two trips are necessary. The worker could supply 215 liters of water in an hour from a well less than 100 m from the worksite, and the range is extended to about 350 m with a donkey.⁶⁴⁷ One of the clay workers or the assistant to the former could spend an hour collecting water without significantly affecting the crew's overall rate of production.

Thus, the minimum effective crew to produce 25 regular Protocorinthian tiles every day is four craftsmen with one donkey. A skilled tile former and his assistant shape the tiles, and two clay workers share the jobs of mining raw materials, gathering water, and preparing paste. The model incorporates all of the materials and production steps necessary to produce complete, unfired Protocorinthian roof tiles.

8.C) Firing and delivering Protocorinthian tiles

To complete the model, the tiles must be fired and delivered. The work is divided into three separate jobs: gathering fuel, firing kilns, and transporting tiles to Temple Hill.

First to consider is the fuel. The consumption rates vary widely because the efficiency of the kiln and the maximum temperature affect the total quantity of fuel consumed during firing. Many varieties of vegetation may have been used as fuel. To simplify the problem, however, only wood is considered here because the energy released from dry wood correlates with weight regardless of species.⁶⁴⁸ The

⁶⁴⁷ i.e., transportation for 7 trips at 4 km/hr requires 21 minutes if the water supply is 100 m away; at 350 m, two trips with a donkey take 21 minutes as well. Then, almost 40 minutes remain to fill the jars with 250 liters of water.

⁶⁴⁸ DeLaine 2001, p. 113. The energy released by burning dried wood of various species is approximately 3,850 kCal/kg, as calculated from tables accessed Feb. 5, 2008: <http://www.offroaders.com/tech/heating-with-wood.htm> (apple, white ash, maple, oak, Canadian spruce, and sycamore all release between 3840 and 3880 kCal/kg). Some energy is lost when burning green wood.

consumption of fuel may be expressed as the “clay/fuel ratio,” the weight of fired ceramics divided by the weight of the fuel consumed during firing.⁶⁴⁹ Near Teotihuacan, Mexico, potters firing kilns of 1.86 m³ capacity to 840 °C with pine logs achieved a 1.5 clay/fuel ratio on average.⁶⁵⁰ Two potters in Pakistan reported the equivalent to clay/fuel ratios of 2.6 and 3.2 with unknown firing temperatures.⁶⁵¹ Several firings to 800-960 °C of an experimental kiln in Amarna lasting less than two hours had a clay-fuel ratio from 1.9 to 2.0. One 700 °C firing scored 3.5.⁶⁵² For bricks, DeLaine estimates that 410 kg of wood will fire 1,000 *bessales*, which is equivalent to a clay/fuel ratio of 4.75.⁶⁵³

An alternative measure is the fuel consumed per cubic-meter capacity of the firing chamber. In DeLaine’s estimate, about 265 kg of wood are needed to fire one cubic meter of densely stacked bricks.⁶⁵⁴ Burning about 400 kg of wood raised the one cubic-meter chamber of an experimental black gloss kiln to 900 °C, but only about 300 kg were needed to reach 800 °C.⁶⁵⁵ Psaropoulou recounts several potters’ descriptions of larger kilns fired with only about 115-200 kg of wood per cubic-meter capacity.⁶⁵⁶ Finally, several Italian kilns fired with olive trimmings consumed between 200 and

⁶⁴⁹ Rice 1987, p. 174; Rye and Evans 1976, p. 165; Sheehy 1988.

⁶⁵⁰ Sheehy 1988, pp. 212-215. The peak temperatures ranged from 786 to 897 °C in multiple firings.

⁶⁵¹ i.e., 1800 kg vessels / 700 kg wood and 1600 kg vessels / 500 kg wood: Rye and Evans 1976, p. 165. Sheehy questions the reliability of these ratios: Sheehy 1988, pp. 206-207.

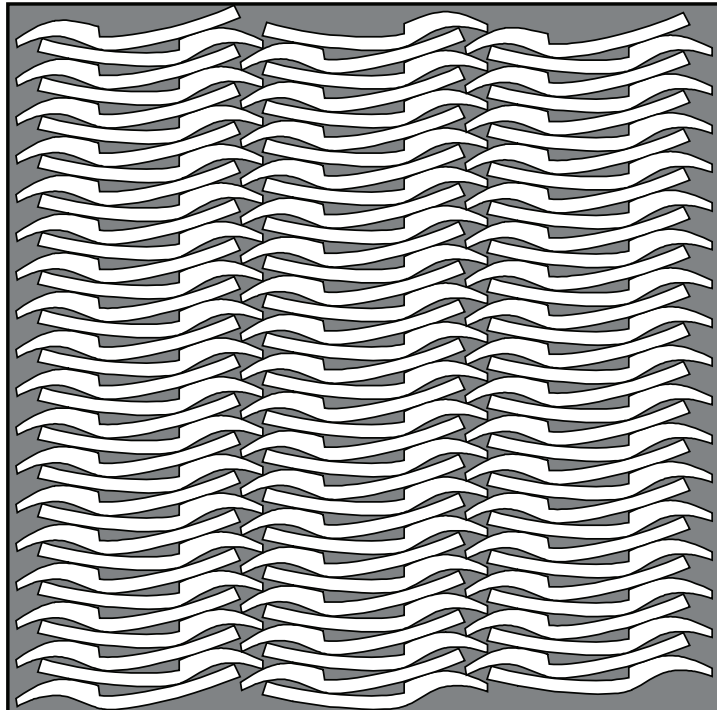
⁶⁵² Nicholson 1995, pp. 250-259.

⁶⁵³ DeLaine 1997, pp. 117-118. She estimates 0.45 tons of wood for 1000 *bessales*. The wood is equivalent to 409.1 kg, and the *bessales* are approximately 19.7 x 19.7 x 2.5 cm, or 0.97 liters each. Presuming an average specific gravity of 2.0 for a relatively light calcareous clay, the 1000 *bessales* would weigh about 1940 kg.

⁶⁵⁴ i.e., 650 *bessales* fit into 1 m³ of kiln space with room for ventilation, so 65% of the 409.1 kg of wood is needed for 1000 *bessales*.

⁶⁵⁵ Echallier and Montagu 1985, p. 144 and fig. 4. The 300 kg for 800 °C is estimated from the firing curve in the figure. The amount cannot be extrapolated precisely because the text reports fuel consumption rates that are impossibly high.

⁶⁵⁶ Psaropoulou 1984, pp. 114-123 (Samos), 148-155 (Chios), 184-191 (Lesbos), 238 (Lemnos). At Samos, Chios, and Lesbos, kilns with capacities of ca. 9 m³ were fired with 800 to 1000 okades of wood (1020 to 1270 kg), whereas 300 to 350 okades of wood (380-445 kg) fired a kiln from Lemnos with about 2.2 m³ capacity. An oka is equivalent to 1.27 kg: Blitzer 1990, p. 687; Ionas 2000, p. 243. The anecdotes from Psaropoulou may not be reliable.



**Figure 8.5 Optimal kiln stacking arrangement
for 104 Protocorinthian tiles inside a 2.15 m square (view in plan)**

270 kg per cubic meter.⁶⁵⁷ These numbers are variable, but at least low-temperature, wood-fired kilns generally have clay/fuel ratios within the range of 1.5 and 4.75, and the majority consume 200 to 300 kg of wood per cubic meter of capacity.⁶⁵⁸ The latter estimate is less variable and thus will be used to compute the fuel consumption for a Protocorinthian tile kiln.

The size and shape of the ancient kiln are constrained by the complicated shape of Protocorinthian tiles. Their profiles make the tiles difficult to place efficiently. The firing chamber may have been designed to fit a maximum number of tiles without wasting space. A tile is stable only when stood on its back end, which limits the possible stacking arrangements. Considering the front profile of the tiles, one arrangement immediately stands out as the most efficient. Viewing their front faces in

⁶⁵⁷ Hampe and Winter 1965, p. 227 table 1: small and medium kilns at Cutrofiano, Lucugnano, and S. Pietro with capacities of 8-12 cubic meters were fired with 1800-3200 kg of olive wood.

⁶⁵⁸ See also: Hasaki 2002, pp. 102-108, especially 107-108, with a suggestion that a full ton of wood would be needed for every cubic meter of kiln space.

plan as they would be seen from above, tiles can be stacked in rows where each one is oriented in the same direction (Figure 8.5). Left-handed and right-handed tiles alternate within the rows, leaving a gap just wide enough for air circulation. By staggering the spacing, rows of tiles can be packed closely to one another. This pattern fits well into a rectangular space. Only one square meter fits almost 25 tiles which occupy 70% of this area, leaving less than 30% of the space unoccupied. Other configurations are not as dense.

Only foundations have been preserved from Geometric and Archaic kilns, so their full capacities must be estimated. The floor of the firing chamber of an average kiln is about 1.5 m² in area. The largest round kiln approaches 7.0 m², and an exceptionally large rectangular kiln excavated at Aigion has a 17.5 m² floor.⁶⁵⁹ Assuming a height of one or two meters, these kilns would have capacities between 1.5 and 35.0 m³. It is reasonable to assume that a relatively large kiln was used to fire Protocorinthian tiles. The spacing diagram (above, Figure 8.5) shows an efficient arrangement with three rows of tiles in a square floor 2.15 m on a side. A total of 104 tiles fit into the kiln, but at 0.65 m high, an upper layer of tiles could be set in columns perpendicular to the lower layer. Stacking two layers is feasible because the transverse dimension from the front to the back face of the tiles is very consistent. However, the floor would have to be very sturdy. With 50 tiles/m² in two layers, the floor must support about 1,630 kg/m², which is within the load-bearing strength of mud-brick kilns.⁶⁶⁰ Accordingly, the chamber could have been 2.15 x 2.15 x 1.40 m and have a capacity of about 6.5 m³.

⁶⁵⁹ Hasaki 2002, pp. 221-222 (Geometric), 227-229 (Archaic), 334 (Aigion). Most Archaic and Geometric kilns are round with an average diameter of 1.4 m. The sixth-century BC Aigion kiln is 4.50 x 3.95 m.

⁶⁶⁰ i.e., 25 tiles weighing 31 kg each total 775 kg/m² after they have lost approximately 5% of their weight from firing. Also see: Hasaki 2002, p. 277 and note 51; Rostoker and Gebhard 2001, pp. 216-217.

The clay/fuel ratio for the experimental firing was 3.5, and 140 kg of wood fired the one cubic-meter chamber. These quantities indicate a relatively efficient firing, although this is to be expected from the kiln's horizontal-draft design, its soaking temperature of only 750 °C, and its relatively light charge (about 27% ceramics and 73% unoccupied space). The majority of the Protocorinthian tiles probably were fired at temperatures between 800 and 900 °C in a densely-stacked, updraft kiln. Similar to the brick clamps for *bessales* analyzed by DeLaine, the tile kiln might have been fired by 250 to 300 kg of wood per cubic meter.

The full charge of 208 tiles would have weighed close to 6,500 kg after firing.⁶⁶¹ With 250 kg of wood per cubic meter in the kiln, the whole batch would have been fired with 1,625 kg of wood or its equivalent in another fuel. The clay/fuel ratio is approximately 4.0, slightly more efficient than the experimental kiln with its incomplete load. Such a ratio is higher than some ethnographic records for pottery but lower than DeLaine's calculations for bricks. About 7.8 kg of wood is needed to fire an average tile weighing 31 kg. Because the roof for the Old Temple may have required only 1,491 tiles, even with a 10% allowance for misfires and the stockpile for later repairs, just eight loads with this moderately large kiln are necessary to fire 1,664 tiles for the whole roof. Although there is no allowance for breakage, the 204 tiles with dark paint could have been fired together in one kiln load in order to control a reducing atmosphere. It may have been possible to use an existing Corinthian kiln, which would have saved some time for the project. With a full crew, however, constructing a new kiln from mud bricks should not have taken more than a week.⁶⁶²

⁶⁶¹ i.e., 208 tiles of 31 kg each weigh 6448 kg.

⁶⁶² Hasaki 2002, p. 75.

8.C.1) Gathering fuel for the kiln

At this point, it is possible to integrate the schedules for shaping the tiles with the firing. The four workers would have finished 208 tiles in less than 9 full work days. The tiles would have been left to dry for at least 3 days before firing, and fuel must have been stockpiled.

Only a rough estimate for gathering fuel is possible. The actual rate is highly dependent on the types of vegetation growing in the vicinity. Potters in twentieth-century nucleated industries are often forced to travel long distances to find firewood, or else they rely on agricultural byproducts such as olive trimmings or straw. Starting with the higher quantity of wood per load of 1,625 kg, it is assumed that craftsmen travel on average 4 km from the worksite to gather wood. The particular distance is arbitrary, but it acknowledges that potters generally must travel farther to obtain firewood than clay. Adopting the same quantities for mining clay, one worker with a donkey can gather 130 kg per load and travel at 4 km/hr. Enough fuel for one firing is gathered in 25 hours, which is less than 3 days of work. The job could be distributed over the 9 days spent forming tiles without adding another worker.

The firing cycle takes several days. Typically, two workers load and unload the kiln. If they place one tile every minute, the chamber is filled in less than 3.5 hours. The kiln could be sealed and ready for firing in 5 hours. A standard firing schedule lasts about 24 hours, with a 12 hour pre-firing and a 12 hour full firing attended by at least two workers.⁶⁶³ With three days to cool off and another 5 hours to unload, the firing itself requires about 34 hours of labor, occupying two workers for a little more than 3 days of a 5-day cycle.

⁶⁶³ e.g., Cardew 2002, p. 191-192; Hampe and Winter 1965, pp. 49 (40 hr), 104-105 (24 hr), 107 (24 hr), 113 (24 hr), 116-117 (24 hr), 117-118 (24 hr), 119-120 (48 hr), 155 (12 hr), 163-164 (24-34 hr), 195-196.

8.C.2) Transportation of fired tiles to Temple Hill

In this model, a worksite near the Agios Antonios or Aetopetra clays has been presumed, which is approximately 4.5 km from Temple Hill. If 5% of the tiles are lost during firing, then 1,581 tiles must be transported, so that 1,491 can be installed on the roof with 90 in reserve. The total weight is approximately 49,000 kg.

This task might have been performed all at once, or else batches of fired tiles could be moved gradually. The job is not equivalent to moving raw materials, because the tiles are awkward and prone to breakage. They cannot be thrown into sacks, and it would be risky loading three tiles onto a donkey. One craftsman could carry a single tile on his own, but each 4.5-km round trip takes 2¼ hours walking at 4 km/hr. All four crew members working together would take 839 hours—about 2.5 months—to complete the task.

A better strategy would be to hire a cart drawn by oxen or mules. A pair of oxen is able to pull about 650-680 kg at 2.9 km/hr, equivalent to a load of about 22 tiles.⁶⁶⁴ Buffered by soft material, a few layers of tiles could be stacked up vertically on a cart bed. Loading one tile per minute, two workers are able to prepare the cart in less than half an hour. With the delivery speed of 2.9 km/hr, 22 tiles can be loaded at the worksite, delivered and unloaded at Temple Hill, and returned to the worksite in four hours. The job would be completed after 72 cartloads and 288 hours. Out of this time, two workmen would load and unload the cart for 65 hours, and at least one of them must have traveled with the cart. The 3,560 man-hours for the four crew members to carry tiles individually would be reduced to 353 man-hours with the ox cart.⁶⁶⁵

⁶⁶⁴ Cotterell and Kamminga 1990, p. 207 table 8.4 (680 kg); Salmon 2001, p. 200 (“half a ton”); Xenophon *Cyropaedia* 6.1.54 (25 talents per pair). A pulling power of 3000 kg is claimed for oxen with a modern harness in Pakistan: Rye and Evans 1976, p. 119.

⁶⁶⁵ The cart is an ideal solution for the final delivery because it is likely that roads connected the worksite and Temple Hill. Donkeys are preferred for acquiring clay and mudstone in the model,

8.C.3) Specialized types of tiles

Until now, the model has assumed that only regular Protocorinthian tiles were manufactured. In reality, the 1,491 tiles of a 20 x 70 roof would have included 1,188 regular tiles (79.7%), 172 eaves tiles (11.5%), 41 free covers (2.7%), 40 hip tiles (2.7%), and 50 ridge tiles (3.4%). The roof actually would have weighed approximately 46,191 kg, which happens to be almost identical to the 46,221 kg of 1,491 regular tiles assumed in the model. The overall calculation is not significantly affected by this discrepancy of 30 kg of fired tile fabric.

8.C.4) Base molds for tiles

Equipment is the final requirement for the job. The basic tile-making tools are standard equipment for potters. Wood template frames could have been created in a few days, allowing for some time to adjust the configuration of the frames. If the master tile former had a clear idea of how to carry out the project, a planning period of one week is conceivable.

The heaviest equipment, however, is the set of 30 base molds. If tile makers produced only hip tiles for two days, they would be forced to produce 30 special molds instead of 2, so the crew has a strong incentive to make all types of tiles each day of production. Distributed proportionately to the numbers of tiles on the roof, the worksite should have 23 bases for regular tiles, 4 for eaves tiles, 2 for hip tiles, and 1 for the ridges. The configuration allows for some day-to-day variability in the rate of production.

The 30 base molds are created in relatively little time. Somewhat more clay and mudstone are necessary in each mold than regular tiles, but the whole job could

because it is unlikely that easily navigable roads had been developed to mudstone deposits, and the worksite is located near the clay source.

have been completed in two days of normal operation. The molds must be left to dry for at least two or three days, and ideally they would have been fired over the normal five-day cycle.

Although very speculative, the preparatory period may have completed in less than three weeks. Allowing 9 days for planning and shaping molds, 2 for drying them, 2 for firing the kiln, and 2 more before removing and installing the molds, about 15 days of work are in order, and perhaps 17 days total with 2 days of breaks. The whole crew would not have been busy during this period, so the clay miners might have started stockpiling materials at the worksite. If a kiln had to be constructed as well, this would have been the first task, adding about a week to the total time. In all, the preparation for tile production should have completed in less than a month or even as little as two weeks if the crew used an established worksite with a kiln and had a clear idea of how to go about designing the tile frames.

8.C.5) *Final model for tile production*

At this point, the model incorporates all aspects of tile production. It is possible to refine the schedule of activities for the four crew members over the 11-hour daily routine. It has been demonstrated that two tile formers could produce 30 tiles in one day, but due to accidents and breakages, a daily rate of 25 tiles was selected as a more realistic estimate. This figure may be revised down to 23 tiles per day, a rate which still fills the kiln in 9 days of labor. Following the example of the Thrapsano potters, all the workers spend some time treading paste so that the former and his assistant share some of this stressful job with the miners. If one of the miners spends a short time every day to gather fuel with the donkey, there is enough to fire the kiln after 9 days. A possible daily schedule for the four workers is presented in Figure 8.6.

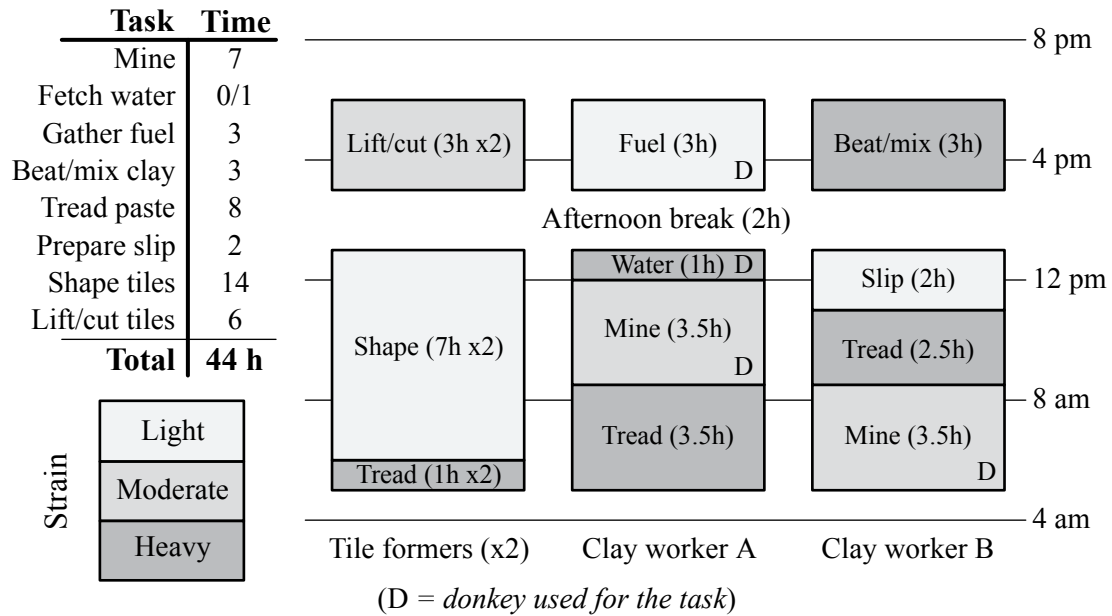


Figure 8.6 Daily work schedule for producing 23-25 tiles

Frequently in ethnographic accounts, potters stop work to monitor a firing even though the process is directed by another specialist. The additional labor for operating the kiln adds up to 73 man-hours, which is close to the labor for one more full-time worker. However, because loading and firing the kilns requires two workers, the normal daily schedule of operations would be interrupted by a firing. A greater efficiency is possible with the same crew of only four members if they take a short break from tile production to manage the kiln together. The minimum effective crew of four could produce 208 tiles in 9 days, rest a day while the tiles dried, and then load and fire the kiln in two more days. They can resume the normal work schedule while the kiln cools. With an additional break day during tile production, 208 tiles can be shaped and fired in a 13-day cycle. Two workers could unload the kiln and load carts with finished tiles during the relatively free time around kiln firings or during another break in production. Although they probably would not have time to accompany the cart to unload tiles at Temple Hill, separate specialists could have managed the carts and organized work at the construction site. The team is able to complete the whole

roof with eight firings in 104 days total. First, they spend 17 days to prepare at a worksite with an existing kiln. The whole 121-day period includes 15 days to prepare and fabricate molds, 72 days of intensive tile production, 16 days of lighter tasks to fire the kiln, and 18 days off work (one day off per week).

The Old Temple roof can be summarized as a total quantity of materials and labor (Table 8.4). The 1,491 tiles are formed from 37,630 kg of dry clay and 8,330 kg of mudstone fired by 11,650 kg of wood. Excluding construction of a kiln, 3,100 man-hours are distributed among the four members of the minimum effective crew, who also keep a donkey to carry raw materials to the worksite. Thus, in an ideal operation without breaks, the whole job is completed in 71 days (or 75 with building a kiln). However, by considering the complex schedule and a percentage of error, the more realistic estimate allows for 103 days of work and 18 days off.

The general model for tile production in seventh-century Corinth derived in the previous chapters predicted a crew size between three and six workers. The efficient production model which is tailored to the performance characteristics of local clays, the geography, and work rates conforms well to these expectations. However, five or six craftsmen may have been recruited for the ancient project, and they may have used

Table 8.4 Minimum time to produce 1,491 tiles and 30 molds without failures

Task	Material	Man-hours
Gather raw materials	46,000 kg clay/temper	430 (105 kg/hr)
Collect water	12,800 L	60
Beat and mix paste	37,100 L (dry material)	220 (170 L/hr)
Tread paste	30,350 L	400 (75 L/hr)
Shape 1,491 tiles	-	1,100
Gather fuel (7.5 loads)	12,200 kg wood	190 (65 kg/hr)
Fire kiln (8 batches)	-	320
Deliver tiles (54 loads)	-	350 (cart)
Shape 30 base molds	-	30
Build kiln	-	0 (/200)
Total	71,000 kg (all materials)	3,100 (/ 3,300)

more than one pack animal throughout the job. It is quite possible the job was completed at an even faster rate than that achieved by the efficient crew of four. Moreover, the actual production would have encountered unexpected setbacks. One collapse of a kiln could destroy many days of work. In review, the whole project might have completed in four months, depending on the numbers of workers and their success in designing and implementing the tile-making system without calamities.

8.D) Conclusions

Given the significance of the Old Temple to the emergence of Greek monumental architecture, it is surprising how quickly the tiled roof, the most ostentatious new element of the building, could have been manufactured. The labor is divided into approximately even thirds for acquiring raw materials and preparing paste (1,110 man-hours), shaping tiles (1,130 man-hours), and firing and delivering the tiles (860 to 1,060 man-hours). About 2,070/2,270 man-hours are spent at the worksite completing tiles. The remaining 1,030 man-hours are for transportation, emphasizing the need for minimizing distance to resources. Even if the tile makers worked less efficiently than during the replication experiments and struggled to design the molds and template system, the whole roof probably was completed within no more than one production season between April and October by a small number of workers.

The scale of the job is comparable to other studies of tiles. Henrickson and Blackman estimate that a small team of artisans could have fabricated a Hellenistic roof at Gordion with 1,000 cover and 1,000 pan tiles in 33 to 53 working days.⁶⁶⁶ After their experiments replicating Protocorinthian tiles at Isthmia, Rostoker and Gebhard produced a much higher estimate for the larger seventh-century tiles. Although they do not propose a detailed schedule, they suggest that more than 300

⁶⁶⁶ Henrickson and Blackman 1999, pp. 313-317.

work-days are necessary for a crew of seven workers to make and fire tiles for the whole roof. With an allowance for breakages, they propose a two-year construction period where tiles are shaped in summer and fired year round.⁶⁶⁷ Besides assuming the tiles are produced at the construction site, they factor no transportation costs into the model.

The Archaic Temple to Poseidon at Isthmia is assumed to have been larger than the Old Temple, with about 1,820 tiles in a recent appraisal.⁶⁶⁸ According to the review undertaken above (section 3.D), the total number of tiles might have ranged from 1,633 to 1,944 tiles for a full width of 22-26 tiles and length of 70-71 tiles. Because the labor to produce the tiles at Isthmia would not have differed significantly, a direct comparison to the Old Temple at Corinth is possible. Assuming the same distribution of resources at Isthmia, the job of producing 1,820 tiles should be 1.22 times larger than 1,491 tiles, increasing the man-hours to 3,800 (or 4,000 with building a kiln). Of this extrapolated total, only 2,500 man-hours are for on-site fabrication of the tiles, whereas the 1,300 man-hours for transportation of raw materials and fired tiles are not reliably applied to the geography around Isthmia. If the distances are assumed to be equivalent at both sites, the minimum effective crew is able to complete the full job in 87 days, although the realistic schedule is longer. At Isthmia, 10 firings of the kiln are necessary to accommodate an extra 13% for breakage and a tile stockpile. The crew of four would prepare for 17 days and form, fire, and deliver the tiles over 130 days. The total project time is still less than 5 months, short enough to complete in one pottery production season. Lowered distances and extra crew members would have reduced the total duration of the project. Moreover, the Isthmia team should have worked more efficiently after the experience at Corinth.

⁶⁶⁷ Rostoker and Gebhard 1981, p. 225.

⁶⁶⁸ Gebhard 2001, p. 58.

CHAPTER 9: MANUFACTURING TECHNIQUES OF THE PROTOCOLINTHIAN TILE SYSTEM

With new data from the replication experiments, it is possible to refine the hypothesis for the forming and finishing sequence of Protocorinthian tiles. Only the regular tiles have been considered in detail up to this point. In this chapter, the evidence is synthesized for every tile type. First, the surface markings on Protocorinthian tiles are classified and analyzed. Next, the hypothesis for forming the regular tiles is revised. The geometry and surface markings of the specialized types of tiles suggest modifications to the production sequence for regular tiles. Although the roof of the Old Temple at Corinth is the focus, the variations of other Protocorinthian roofs are discussed.

9.A) Surface markings of Protocorinthian tiles

The terminology here has been adapted from *Pottery Technology* by Owen S. Rye, an experienced potter and ethnographer.⁶⁶⁹ His book focuses on the interpretation of the macroscopic traces left on ancient ceramics. Most production techniques used on ancient tiles are familiar from traditional ceramics workshops across the world. The only exceptional feature of the Protocorinthian tiles is the post-firing chiseling during their installation on the roof. The replication experiments attempted to reproduce each surface finish.

Three features of the fabric are critical to determining the manufacturing sequence.⁶⁷⁰ First, the fine clay paste reacts to tooling differently as it dries and stiffens. For example, it is clear that the notch was cut out earlier than the cover rabbet, which must have been cut into relatively hard and resistant clay. Second, tools

⁶⁶⁹ Rye 1981, especially pp. 20-24, 59-87. Also considered: Hamer and Hamer 2004; Rice 1987; Shepard 1956; Vandiver and Koehler 1986.

⁶⁷⁰ See above, notes 297, 298, 315.

differently affect the mudstone temper depending on the malleability of the clay. Third, the surface color indicates whether a feature was cut into a tile after firing. Although the fabric varies from pink to yellow, the surface and outermost 5 mm of most tiles is very pale brown (near 10YR 7/4), whereas the rest of the core has fired more consistently to reddish yellow (near 5YR 6/6).⁶⁷¹ This gradation indicates whether the tooling took place before or after firing, because any features with reddish-yellow faces could have been cut into the tile only after the color differences were introduced in the kiln.

9.A.1) *Workability of the paste throughout the forming and finishing sequence*

The workability of the clay gradually decreased as the Protocorinthian tiles were constructed. During the primary forming, the tile must have been built from wet, highly plastic clay that was unable to support its own weight. The cover was notched, and slip was applied soon after the upper surface was formed. The final trimming of the rabbet occurred after the tile had dried leather hard, when the clay had lost most of its plasticity but was still able to be cut with a blade or tensioned string. After the majority of the pore water had evaporated, the tile was bone dry and ready to fire.

In the leather-hard or bone-dry state, the clay could not regain its plasticity without soaking in water for a long time, which would destroy the tile. Thus, any problems that developed as the tile dried could only be corrected by subtractive processes or else by destroying the whole tile to reclaim the paste. Some tiles were reworked late in the construction sequence, evidently to correct such errors rather than discarding the tile. In general, tiles were re-cut only after the firing.

⁶⁷¹ Six exceptional tiles are fired yellow throughout, perhaps due to higher firing temperatures. See above, note 354.

Table 9.1 Surface markings grouped by manufacturing stages

Primary forming	Secondary forming	Surface modification	Post-firing
Laminated temper	Soft clay: notch, corner bevels	Soft clay: slip, smoothing, fingerprints	Chiseling
Gravel parting agent	Leather hard: rabbets, some corner bevels	Dark paint	Sanding
Trimmed edges	Cutting guidelines	Setting guidelines	Weathering
Framed edges			

Each production step in the preliminary hypothesis was inferred from distinctive surface markings, although much of the evidence for the primary forming had been removed by later surface modifications. The range of surface markings may be reduced to the thirteen general categories grouped in Table 9.1. Tool marks are critical for assessing many of these processes. The tools frequently left casts—partial or full impressions of their working edges—in the fabric. Sorted temper fragments at the surface are indirect evidence for tooling. Temper particles may be caught and dragged by an instrument, leaving a hollow behind the particle in the direction of the stroke (e.g., below, Figure 9.2).⁶⁷² If these “dragged temper tracks” are consistently oriented, then the bearings of the hollows are at the angle of the original stroke. The position of the temper fragment within the track shows which direction the instrument was moving. The tool moved toward the side of the track where the temper fragment is lodged.

Post-firing processes should be categorized separately because not all were part of a repeated and predictable forming sequence. Because most tiles were tailored to fit with their neighbors during installation, most retooling was instead an ad-hoc modification of an imperfect but otherwise finished product.

⁶⁷² Rye 1918, pp. 59, 86-87.



Figure 9.1 Laminated fabric (FR 117; 3 cm scale grid below)



Figure 9.2 Dragged temper tracks (FT 211)

9.A.2) *Features associated with primary forming*

Lamination (Figure 9.1): The mudstone temper particles are clearly aligned where visible on the unslipped back faces or vertical sections exposed in breaks. Viewed from the sides of the tile, the elongated, platy fragments of temper embedded within the fabric are oriented with their short axes perpendicular to the bottom contour of the tile. A small number of elongated voids are oriented in the same direction as the temper. Near the edges of some fragments, particularly of eaves tiles, the laminae curl up or down to parallel the side face. No sorting is apparent when viewing the fabric from above or below in horizontal breaks.

The lamination is a result of slab-building techniques.⁶⁷³ Sheets of clay are rolled or beaten over a flat surface, such as a mold. The pressure exerted against the clay orients the short axes of elongated inclusions or voids on the plane perpendicular to the direction of force. The curling at the edges of some tile fragments indicates that the clay had first been pressed against a vertical surface at the sides of the tile, similar to the wooden frames in the tile-making apparatus proposed in Chapter 5 (above, Figure 5.7).

⁶⁷³ Rye 1981, pp. 71-72, 81, 84-85; Whitbread 1996; Vandiver 1987.

Gravel parting agent (above, Figure 5.1): The undersides of most tiles are coated in a fine gravel not found on any other surfaces.⁶⁷⁴ The gravel is composed primarily of crushed mudstone fragments similar to the temper mixed in the fabric, but particles of other stones or clay also adhere to the surface. The patches of gravel and clay do not always cover the entire bottom surface, and, in some areas, the tile paste appears to have rested directly against the mold without sticking. It is possible that dried clay powder and dust were also used for this purpose, but these agents would not have left prominent macroscopic traces on the surface. Fine sand or dry powdered clay are the parting agents traditionally used by potters.⁶⁷⁵

Trimmed edges (above, Figure 5.6; Figure 9.2): Dragged temper tracks on many regular tiles indicate that the back face was trimmed. Left by a knife or spatula, the stroke approximately parallels the bottom contours of the tile. These faces also exhibit some relief. Ovoid bulbs of clay have been raised above the surface by projecting fragments of temper. Because a blade would cut out only a straight plane, the bulbs must have been extruded later by pressure from above, perhaps while the upper surface of the tile was worked. The bulbs could have been lifted in this manner only when the clay was very wet, which indicates that the upper surfaces were pressured immediately after the frames were removed.

The free side of the pan is tilted inward from bottom to top, its face oriented perpendicular to the rising contour of the underside (as above, Figure 3.8). However, unlike the back edge, this face seldom preserves any dragged temper tracks. Instead, it is dominated by projecting bulbs of clay and narrow crevices, both of which are elongated on the horizontal axis (Figure 9.3). Because the side

⁶⁷⁴ See above, notes 293, 294.

⁶⁷⁵ See above, notes 295, 296.

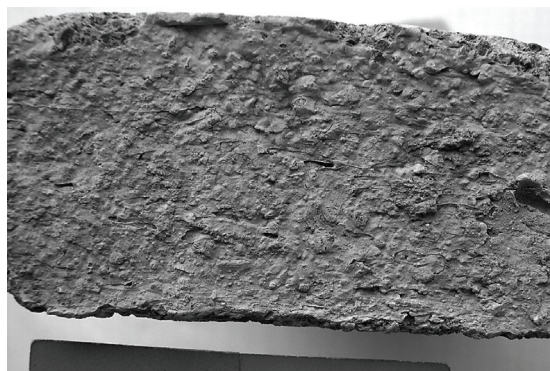


Figure 9.3 Free side of the pan (FP 344; 3 cm scale grid below)

frame is unlikely to have been tilted inward at the angle of the free edge of the pan, the face must have been trimmed with a blade after the tile was formed.⁶⁷⁶ The elongated bulbs and crevices in the surface, which must have been due to later pressure from above, may have obscured many of the dragged temper tracks left by a blade stroke. The tracks would have been horizontally oriented, making them difficult to distinguish from the similarly oriented bulbs and hollows.

Framed edges (Figure 9.4): The free face on the pan of some eaves tiles preserves more direct evidence of a vertical frame. These surfaces are smooth except for short, horizontal dragged temper tracks. Unlike those on the trimmed edges of regular tiles, the tracks are short. No bulbs of clay have risen above the surface, which, except for the hollow tracks, is a smooth plane. Such a plane could have been created only against the face of a vertical frame. The clay, however, is prone to sticking to the frame because the parting agent would not have adhered to the vertical surface. The frame may have been pulled a short distance to separate it from the molded face, which would have produced some drags. The free edges of other eaves tiles, however, preserve clear indications of a blade used to separate the tile from the frame. The stroke often did not reach the whole surface, leaving

⁶⁷⁶ Because the edges are trimmed, the process technically should be classified as secondary. However, the cutting indicates the use of a frame, which is an essential component of the primary mold.

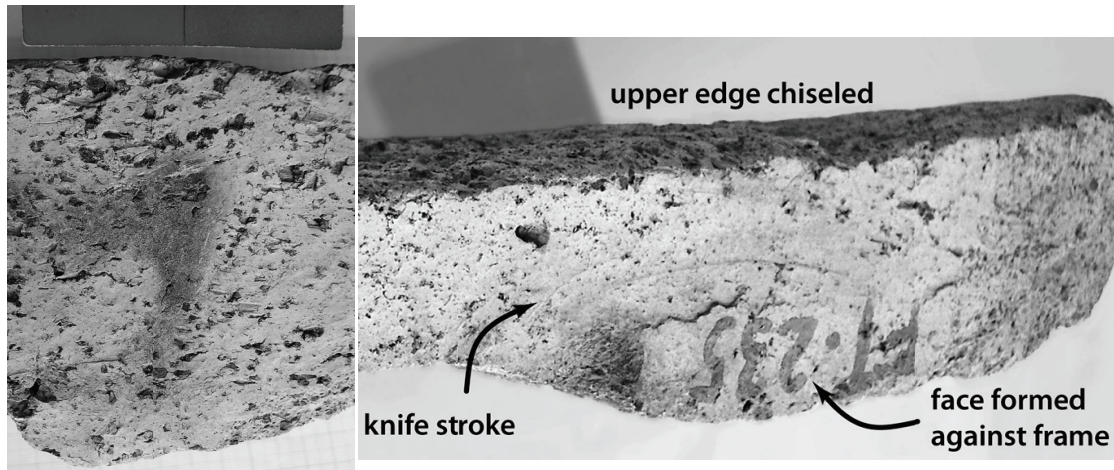


Figure 9.4 Free sides of eaves pans formed against a vertical frame: (left) FP 161 (3 cm grid scale at top); (right) FT 235 (face height ca. 6 cm)

portions of the molded face intact at the lower edge of the tile. In these cases, it can be seen that the knife cut the molded surface back by less than a millimeter (Figure 9.4, right).

The overall longitudinal dimension of eaves tiles is about two centimeters larger than that of the regular tiles because the pans of adjacent eaves tiles must abut one another (above, Figure 3.7). In contrast to the regular tiles, whose pans were cut back on the free side immediately after molding, the free sides of the eaves pans were left intact. Consequently, only eaves tiles preserve impressions from the molding frame at the free edge of the pan.

9.A.3) *Features associated with secondary forming*

Cuttings into soft clay: The surfaces of the notch of most tiles have dragged temper tracks (above, Figure 5.8). Bits of clay have occasionally been smeared over the surfaces of the notch as well, most often its bottom face. In some cases, the blade has cut into the adjacent face, leaving a gash with raised clay at its edges. All of these features indicate that the clay was relatively soft when the notch was cut.⁶⁷⁷

⁶⁷⁷ Rye 1981, p. 66, fig. 47.

At times, the faces of the corner bevels have a similar consistency to the notch faces. The majority, however, appear to have been cut after the clay had dried (see below). Most bevels were chiseled back after firing, obscuring the original surface markings.

Although not an intended result of the manufacturing process, finger impressions are preserved on the back faces and the free end of the pan of several tiles (above, Figure 5.10).⁶⁷⁸ As already discussed, these impressions must have been left by craftsmen who were attempting to shift the tile from the base mold prematurely, before it had dried leather hard.

Cuttings into leather-hard clay: Another form of tooling, typical of the cover rabbets, appears to have been cut into relatively stiff clay (above, Figure 5.9).⁶⁷⁹ The tooled surfaces have long, smooth strokes which are roughly parallel. The strokes can have been produced only with a flat-tipped metal tool resembling a spatula. The path of each stroke is a relatively smooth plane, and dragged temper tracks are very short and inconspicuous. Most pieces of temper appear to have been forced down below the surface of the stroke. Some mudstone temper has been fractured by the blade and smeared over the surface of the stroke. In order to be pulverized by the blade, pieces of temper must have been fixed in place by relatively stiff clay (see above, Figure 5.14, in the lower part of the field). These features indicate that the clay was leather hard during this tooling.

The faces of the corner bevels often preserve tooling with similar characteristics. Although too small for any long strokes to be apparent, the faces are smooth and contain pulverized fragments of temper.

⁶⁷⁸ See above, note 305.

⁶⁷⁹ The width varies only slightly from tile to tile, although the dimension varies more from site to site.

Cutting guidelines: Several tiles have incisions in the bottom paralleling the edges of the underside rabbets. These guidelines may have been cut into many more tiles to mark the edges of the rabbets, but, if this were the case, most were subsequently removed when the rabbet was cut. Generally, the incisions are shallow and the edges are not raised, which is consistent with cutting leather-hard clay.

9.A.4) *Surface modifications*

Buff slip: All the faces of the tile that would be visible on the roof were coated with slip. The slip is indistinguishable from the fine body clay but is untempered. Never appearing to have pooled or dribbled like a fluid, it adheres well to vertical faces, which suggests that the slip was a relatively viscous slurry rather than a liquid during its application.⁶⁸⁰ With few exceptions, its application obliterated most of the tool casts from the primary forming of the external faces (above, Figure 5.4).

Dark paint: A few tiles at Corinth were also painted black over the pale slip (above, Figure 5.13). Like the slip, the paint is applied only to visible surfaces. On the upper surfaces, however, a narrow band along the edges of the tile at its back side and the free side of the pan is unpainted. The tile makers anticipated that the area of the reserved band would be concealed on the roof by its overlapping neighbors. The paint clearly had been applied as a very thin liquid wash, and dribbles indicate that the tile was tilted up on its back end during the painting (above, Figure 5.13). The wash varies from reddish brown to dark gray.⁶⁸¹

⁶⁸⁰ Also see: Rye 1981, p. 20.

⁶⁸¹ See above, notes 308, 309.



Figure 9.5 Eaves pan rabbet, free edge (FT 211; front face at bottom; 3 cm grid scale)

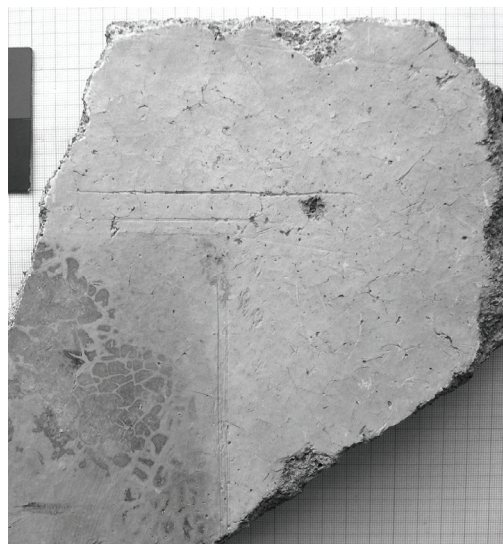


Figure 9.6 Back free corner of the pan with incised guidelines, weathering; (FP 109; 6 cm scale)

Setting guidelines (Figure 9.6): Grooves incised into the slip and paint on the upper surface mark the intended setting positions for adjacent tiles. The guidelines parallel the back edges of the tile and the free edge of the pan, although they are discontinuous or missing in many cases. A few ridge and hip tiles also have guidelines incised into the front faces of the pan, although it would have been unnecessary to mark the intended setting position on the tile below. The edges of the incisions are sharp, suggesting that the tile had already dried leather hard.⁶⁸² Because they also cut the black paint, the guidelines probably were the last feature added to the tiles before firing.⁶⁸³

9.A.5) Post-firing modifications

Chiseling (above, Figure 5.14): Chiseling is the only finishing process of

Protocorinthian tiles which is not commonly observed on traditional pottery. Color variations confirm that this tooling occurred after firing. Unlike the markings from

⁶⁸² See above, note 306.

⁶⁸³ i.e., FP 108, FP 158, FP 335, FT 224

the pre-firing stages, all of which have the same buff surface color, the clay is noticeably redder where the tile has been chiseled.

Chiseled faces are rough and irregular, and some patches are indistinguishable from the unintentional post-firing breaks. However, the chiseling generally occurs only on the joint surfaces, which would have required trimming in order to rest flush with the adjacent tiles.⁶⁸⁴

The tool casts are unmistakably the marks of chisels (above, Figure 5.14).⁶⁸⁵ The chisel was struck repeatedly to drive it along a path. The fired clay and the temper were pulverized by the blows, leaving behind densely spaced parallel grooves in the direction of the stroke. Each path ends in a rough, pitted surface from which fragments of temper have been dislodged—the last stroke in the sequence. Because each successive stroke of the chisel tends to cut deeper into the surface than the previous one, the chisel must be raised after several strokes in order to avoid overcutting. As a result, the surfaces of the paths are scalloped. A low ridge perpendicular to the course of the path marks wherever the tip of the chisel was raised (above, Figure 5.14).

Sanding (Figure 9.5): In order to rest securely over a horizontal wood fascia, the pan rabbet for the eaves tile must be smoother than that of the regular tile. Similar to the chiseled areas, the pan rabbet is reddish, which indicates that it was retooled after firing. However, there are no irregular breaks or scalloped paths characteristic of the other chiseled features. Although the eaves rabbet may first have been chiseled roughly to the desired level, it appears that the surface was polished afterwards with an abrasive material.

⁶⁸⁴ Also see above, note 311.

⁶⁸⁵ For a detailed description of chisel marks on limestone, see Rhodes 1987b.

Weathering (Figure 9.6): Although not part of the manufacturing process, exposure to the elements discolored the external faces of most tiles after their installation on the roof. The weathered surfaces are stained shades of dark brown or orange in irregular, flowing patterns. The amount of weathering varies dramatically from one tile to the next. The weathering may be a barely perceptible, such as a pale-orange discoloration near the setting lines, or whole surfaces may be covered by deeply saturated stains. The black paint appears to have been impervious to weathering, which makes the original setting position of the adjacent tiles difficult to discern.

9.A.6) *Casts and other indirect evidence for tools*

Spatula: The cuttings into leather-hard clay, in particular the rabbets, clearly preserve tool casts from a flat, sharpened blade resembling a modern paint scraper or a narrow chisel. Because the clay was hard and resistant when the rabbets were cut out, it is likely that the blade was metal rather than wood.

Both sides of the blade are clearly preserved on many examples. The width of the tool varied from 2.1 to 2.7 cm at Corinth,⁶⁸⁶ from 2.1 to 3.5 cm at Isthmia,⁶⁸⁷ and from 2.15 to 2.75 cm at Delphi.⁶⁸⁸ Although some variation in the stroke width might have been introduced by holding the blade at an oblique angle to the stroke, instruments of at least three different widths must have been used during the production of each roof.

Earlier in the production sequence while the clay was softer, a blade was used to separate the sides of the tile from the mold and cut out the notch. The traces it left on the tiles indicate that the blade was narrow and at least ten centimeters long.

⁶⁸⁶ From 13 readings. One measurement of 3.25 cm is probably the result of two adjacent strokes.

⁶⁸⁷ From 13 readings. Nine examples are 2.1-2.5 cm wide; the other four are 3-3.5 cm.

⁶⁸⁸ From 3 readings.

Although the tool may have been a knife, the same metal spatula used to scrape out the rabbets may have performed both functions.

Polishing implements: The slipped surfaces of the tile have fine, brush-like ridges. The path of the stroke is often several centimeters wide. The top faces of the cover and pan have long transverse-oriented strokes, sometimes with a perpendicular stroke running along the front or back edges. The bristles of a brush tested during the replication experiments were too stiff to replicate the ancient finish. The original fragments may have been polished with a softer brush, but it is more likely that craftsmen simply used their wetted fingers.⁶⁸⁹

Straightedge: The lateral setting guidelines were clearly generated using a straightedge. The longitudinal incisions—that is, parallel to the back edge of the tile—are irregular, probably because an inflexible straightedge cannot be laid in full contact with the curved surfaces along the profile of the tile.

A pointed instrument was needed to incise the setting guidelines. Rather than postulating a separate tool, it is better to assume that the tip of the spatula blade was reused for this task.

Chisel: In order to withstand the blows from a hammer, a chisel with a sturdier shaft than the spatula would have been necessary. Nevertheless, the chisel casts indicate that the tip was relatively sharp. The widths of the chisel paths vary at Corinth from 1.1 to 2.3 cm across.⁶⁹⁰ The casts on the Isthmia tiles, however, are consistently 2.4-2.5 cm wide.⁶⁹¹ These blades are considerably narrower than the

⁶⁸⁹ Rye 1981, p. 59. Also see above, note 307.

⁶⁹⁰ i.e., 1.1-1.4 cm (7 readings), 1.6-1.9 cm (9 readings), 2.2-2.3 cm (4 readings).

⁶⁹¹ From six readings. From Delphi, one tool cast from a 2.1-cm-wide chisel has been preserved.

flat chisels about 8-9 cm in breadth which were used in the Corinthia during the Late Geometric and early Archaic periods to cut poros limestone.⁶⁹² As demonstrated by the replication experiments, the fired tiles are fragile and must be chiseled gently. The narrow chisels probably were a precaution against fracturing the fired tiles, although the temple builders at Isthmia, who must have had previous experience installing the roof on the Old Temple, favored a slightly wider instrument.

9.B) Refinements to the hypothesis for manufacturing regular tiles

The full production cycle of regular tiles may be divided into five stages: paste preparation, primary forming, secondary forming/surface modifications, firing, and post-firing modifications. Except for these general stages, no single linear sequence of operations can be proposed for the fabrication of ancient Protocorinthian tiles. Not only is the evidence inadequate to make such a determination, but the craftsmen do not appear to have adhered to a rigid sequence. Many production steps are interchangeable, such as applying the slip, cutting the notch, and cutting the corner bevels. Although the corner bevels were cut immediately after the notch during the replication experiments, the timing of this step appears to have varied among the ancient fragments. Moreover, the craftsmen did not always perform each step at the same time. For example, the slip of several tiles had been applied after the paste had stiffened, although this was not the normal practice (above, Figure 5.4). The tile makers neglected to cut the cover rabbet of one regular tile from Corinth, which forced the builders to chisel a makeshift shelf at the front edge of the tile at the construction site (Figure 9.7). Consequently, instead of proposing a complete production sequence,

⁶⁹² Rhodes 1984, pp. 29-32; 1987b.

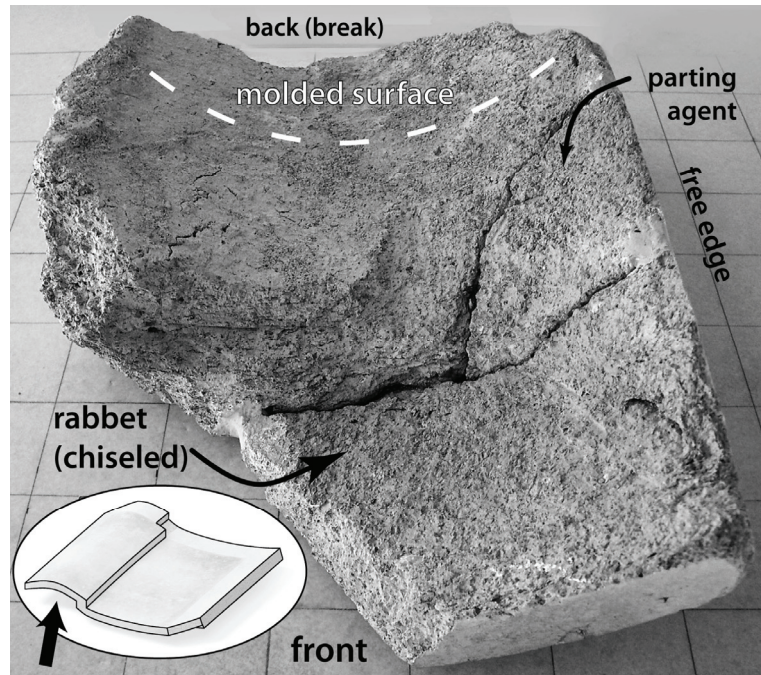


Figure 9.7 Bottom view, FP 327, whose cover rabbet was omitted (5 cm grid)

this analysis focuses on aspects of the hypothesis that may be clarified in light of the replication experiments and the ethnographic survey.

9.C) Paste Preparation

The fabric of the fired replica tiles did not exactly resemble that of the ancient Protocorinthian tiles. The laminae visible in the breaks of many ancient fragments are better sorted (above, Figure 5.2, Figure 6.28, Figure 9.1), and the fabric has very few voids—less than 1% of the total volume. The surface markings of the back face and the free side of the pan indicate that the paste of the ancient tiles was relatively wet during the primary forming. The faces have narrow crevices and horizontally oriented bulbs of clay raised by temper fragments. The pressure from above caused by the application and polishing of the slip probably produced both features. The back face and the free face of the pan are slightly extruded along their upper edges, which would



Figure 9.8 Back face of the pan with extruded upper edge (FP 76)

be expected from pressure only if the paste had been malleable (Figure 9.8).⁶⁹³

Although cutting the replica tiles loose from the frame left dragged temper tracks on the back faces similar to those on the ancient fragments, the faces of the replica tile, unlike the originals, had no extrusions or hollows from pressure. Consequently, when it was pressed into the tile molds, the paste used in the ancient Protocorinthian tiles must have been softer and more malleable than the mixture used for the replica tile.

The experimental procedure of dropping slabs of relatively dry clay on a flat surface before packing them into the base mold is unlikely to have been the ancient method of preparing paste. As an alternative, damp paste from the trodden clay stockpile might have been packed directly into the mold.⁶⁹⁴ In fact, modern tile makers and some producers of large storage jars use very soft paste.⁶⁹⁵ Further experiments are required to test this proposal.

9.D) Primary forming sequence

A fundamental question is how each tile was built to a consistent curve. Every combination tile was formed as a solid unit rather than pieced together from a separate

⁶⁹³ However, the front face and the free side of the cover were coated with slip and polished, leaving no traces of earlier production steps.

⁶⁹⁴ See above, note 624, Figure 4.1, Figure 8.3, Table 8.2.

⁶⁹⁵ See above, notes 236, 629.

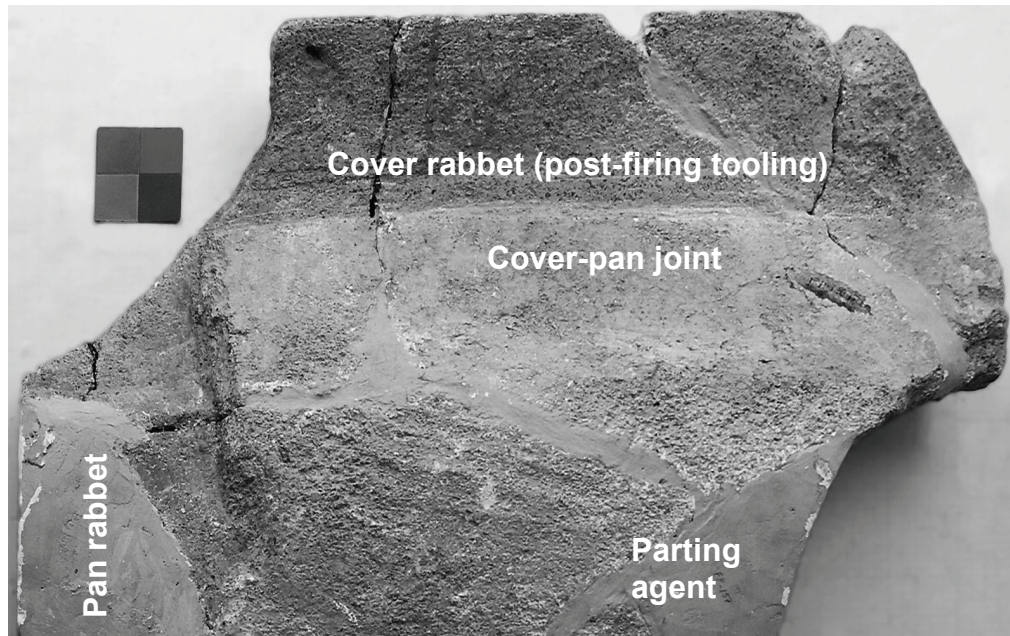


Figure 9.9 Thinned parting agent under the cover-pan joint (FP 157; 6 cm scale)

pan and cover, as revealed by the continuous, laminated fabric across the cover-pan joint.

9.D.1) *Molding the underside*

As argued in Chapter 5, the mudstone parting agent on the underside of most Protocorinthian tiles is the strongest evidence for the determining the orientation of the tile when first formed. The layer of mudstone particles is evenly distributed under the pan, but it thins under the cover (Figure 9.9). If this parting agent had adhered to a slab of clay before it was packed into the mold, then the layer should have been evenly distributed under the cover and pan. However, if the mudstone had originally been sprinkled over an open base mold, few particles would have settled at the cover of the mold where the profile rises at a relatively steep angle (above, Figure 3.8; Figure 5.7). Thus, as in the replication experiments, the ancient procedure must have been to coat the base mold with the mudstone parting agent before adding any clay.

No parting agent adheres to the bottom rabbets. The profile of the base mold must have continued uninterrupted from front to back, as confirmed by the tile lacking a cover rabbet (above, Figure 9.7; compare to Figure 5.15). The mudstone parting agent is found on the undersides of the eaves and hip tiles. As with the regular tiles, their rabbets were secondary cuttings. On the other hand, the undersurfaces of the ridge and free cover tiles seldom preserve any remains of a parting agent.⁶⁹⁶ Instead, only secondary tooling is preserved: the spatulated surfaces of the rabbet cut into leather hard clay, and the rough surfaces chiseled into the tile after firing.

As with the regular tiles, the other types would have been created on base molds with a continuous profile. The molds were coated with a layer of mudstone particles, and clay was packed into the frame to form the tile right-side-up. The mudstone parting agent on the eaves and hip tiles is direct evidence for this procedure, and, by analogy, a similar method would have been used to form the ridge and free cover tiles.

9.D.2) *Transverse bowing and the template system*

Transverse bowing is an important clue to how the top surfaces of the tiles were formed. The phenomenon has already been described and tested, but the results of the replication experiments were inconclusive (Chapters 5, 6). Although at first glance the tiles appear to be flat from front to back along the transverse axis, the top and bottom contours of most tiles rise gently from the edges to the middle (Figure 9.10). As a result, the top surface is slightly convex from front to back, whereas the bottom is slightly concave. As revealed by the comparison of multiple tiles in Figure 9.11, the amount of bowing is inconsistent.⁶⁹⁷ The upper surface bows up no more

⁶⁹⁶ With the exception of ridge tile FR 117, discussed below.

⁶⁹⁷ Several tiles from Isthmia also exhibit transverse bowing but are excluded from the figure. Protocorinthian tiles from other roofs are too fragmentary to analyze.

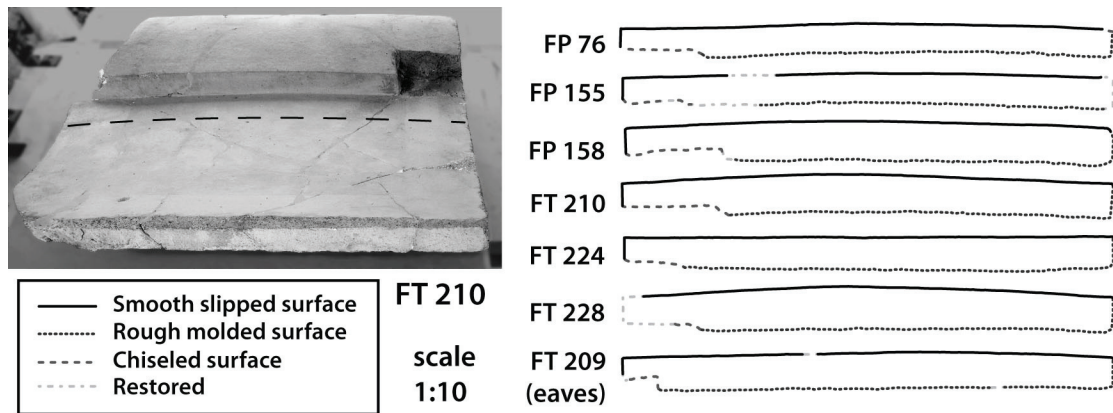


Figure 9.10 Transverse bowing (front face to left; sections near midpoint)

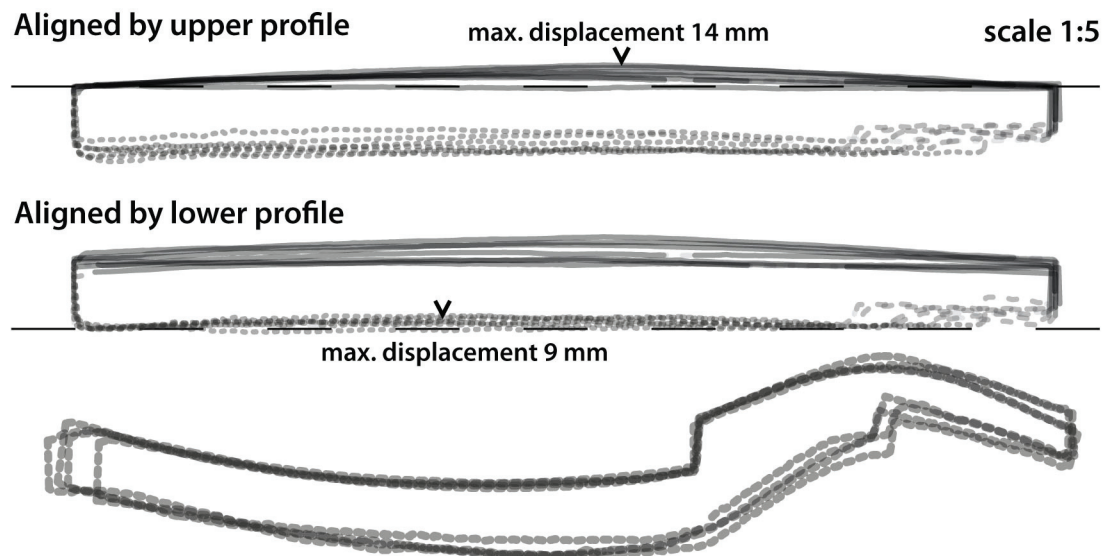


Figure 9.11 Comparison of transverse sections; *(below)* longitudinal sections

than 1.4 cm above the front and back edges. With the maximum offset of only 0.9 cm at the middle, the bottom profiles are less bowed than those on the top. Most tiles bow up at least several millimeters, but several examples are essentially flat. In no case is the surface significantly lower at its center—tiles only bow up, not down. The transverse bowing is too irregular and slight to have been planned. Instead, it must have been an unintended side effect of the manufacturing process.

The characteristics of the bowing indicate that it could have been introduced only during the primary forming. Although tiles may be distorted by drying and firing

shrinkage, this is unlikely to have produced transverse bowing for several reasons. First, the tiles are very thick, which greatly inhibits bending after the clay has stiffened. Leather-hard clay lacks plasticity and splits before it bends. Second, the tiles are very heavy, making it unlikely that they would lift up at the center while resting on the base mold. Third, a distortion induced by drying should not strongly favor one axis over the other. Although the height of the transverse bowing varies up to 1.4 cm, the overlays of the tiles' longitudinal profiles reveal no equivalent variability (compare the top and bottom of Figure 9.11). Instead, only at the free ends of the covers are the longitudinal upper profiles of the tiles significantly variable, probably due to the cutting of the cover rabbet. Fourth, most tiles actually thicken toward the middle because the amount of transverse bowing tends to be greater on the top than on the bottom. Drying shrinkage is unlikely to have caused such an effect. Finally, although the upper surfaces of the replica tiles and test bricks were carefully leveled to a straight transverse profile, none developed any noticeable bowing during drying or firing.

Neither would many primary forming processes produce bowing. For example, a straight top mold similar to that used during the Isthmia replication experiments would not have caused any transverse bowing. Even if the mold were bowed, it is unlikely to produce the wide variation in the amount of bowing observed on the ancient tiles (Figure 9.11).

Although other causes are conceivable, the template system is the most likely explanation of the transverse bowing on the Protocorinthian tiles. This forming method has already been inferred from the consistency of the longitudinal profiles of the tiles; the lack of any mold impressions on the upper surfaces; the parallel striations oriented in the direction of a strike below the slip of some tiles (above, Figure 5.4; Figure 6.16); the resemblance of these striations to the upper surfaces of the replica

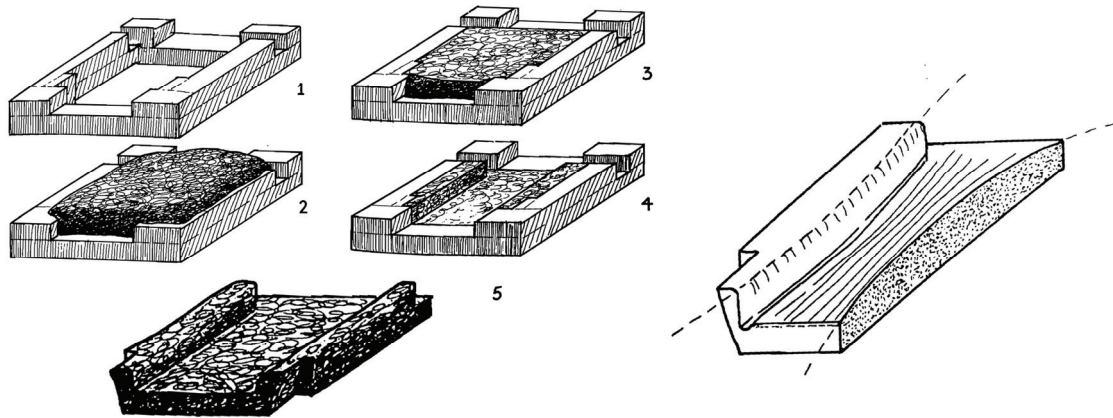


Figure 9.12 System for shaping Roman tegulae: (left) stages of production; (right) distortions from an ill-tensioned wire (Rook 1979, pp. 300-301 figs. 16.3-4)

tiles before polishing; and the widespread use of similar techniques among tile and brick makers in the ethnographic survey. Furthermore, the template system is a better candidate for inducing bowing because the upper surface of the tile is exposed during forming.

Two methods for striking the upper surface with the templates might have caused bowing: drawing a tensioned wire across the templates to cut away excess clay, or, as in the replication experiments, drawing a wood straightedge across the templates. First, if the upper surface were wire cut, there would have been a tendency for the wire to rise slightly at its middle.⁶⁹⁸ During his experimental replications of Roman tegulae, Tony Rook documented this effect of an insufficiently tensioned wire (Figure 9.12).⁶⁹⁹ On the other hand, the wood strike can also produce bowing. In order to keep the strike in full contact with the surface of the tile, the mold at first must be filled with excess clay. As a result, the excess in the middle prevents the straightedge from contacting both template frames at once. Although it is possible to press the board firmly against both templates, the replication experiments demonstrated that this method is ineffective. To avoid opening gashes, the board must be drawn gently over

⁶⁹⁸ In particular, see above, note 303.

⁶⁹⁹ Rook 1979, p. 300. Warry does not comment on bowing during his own experimental tests: see above, note 271.

the surface, gradually lowering the tile over many passes. The upper surface of the tile is initially leveled near the front and back template frames. Extra clay remains mounded at the middle until the final smoothing. Thus, an incomplete striking of a tile can produce transverse bowing. The replication experiments did not simulate the bowing, however, and further tests are required to compare the effects of a tensioned wire and a rigid strike.

To accept the template system as the cause of transverse bowing, the bowing on the bottom of the tiles must also be explained. Because the underside of the tile was shaped on a mold, the surface of the mold must have bowed up toward its center. This slight, unintentional bowing could have been introduced if the mold were created in the same technique as the top of the tile—that is, by striking its profile in clay. Due to its relative simplicity and efficiency, such a mold has already been proposed in the preliminary hypothesis and tested during the replication experiments.

9.E) The primary forming of the specialized types of tiles

The base mold and template system has been demonstrated to be the only viable method for creating the regular Protocorinthian combination tiles. Despite the complexity of the finished tiles, the apparatus is straightforward in its conception and simple to construct. Moreover, the template forming technique may be directly adapted to the specialized tiles.

9.E.1) *Templates for shaping eaves tiles*

First, the eaves tile can be generated by simple alterations to the regular tile mold and templates. In order to rest on a fascia board, the front face of the tile has a shallow pan rabbet cut behind its horizontal lower edge (Figure 9.13; above, Figure 3.11). In response to the peak at the junction of the pans immediately below, the cover

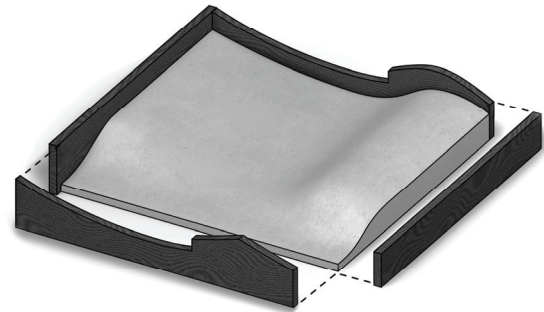
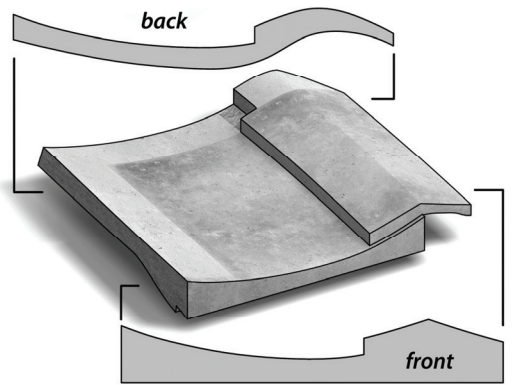


Figure 9.13 Profiles of the eaves tile Figure 9.14 System for shaping eaves tiles

is peaked at its front edge. From front to back, the cover makes a gradual transition from a peak to the curve of a regular cover.

The bottom of the eaves tiles makes a smooth transition from the profile of the regular tile to what must have been a horizontal front edge (above Figure 3.11, right; as Figure 9.14). The tiles must have been molded in this configuration, although the front profile of the base was altered by cutting the pan rabbet (Figure 9.13). The simplest way to produce such a mold is to construct a complete regular tile mold, carve out the horizontal front edge, and smooth the transition. It is difficult to imagine a simpler method for adapting the regular tile design to fit over a horizontal fascia at the eaves.

The templates can be modified to create a peaked cover. Without altering the pan, the cover of the front template would have been peaked (Figure 9.14). The template at the back would have had the regular tile profile. In this system, striking the top with a straightedge produces a smooth transition from the peaked front to the rounded back edge.⁷⁰⁰ As with the base, this simple modification exactly reproduces the shape of the original Protocorinthian eaves tiles (Figure 9.14). After the tile was

⁷⁰⁰ John Lambert successfully produced replica eaves tiles using a mold and frames built to these specifications. The tiles were displayed in the Snite exhibit: see above, note 1.

shaped, the front face of the cover would have been cut back in order to distinguish it from the face of the pan.

9.E.2) Templates for shaping hip tiles

The hip tile, too, can be generated by modifying regular templates. The curved surfaces of the pair of regular tiles from the two adjacent slopes of the roof are combined along the diagonal into a single hip tile (above Figure 3.13). Both halves are shaped exactly as regular tiles. The fabric of the ancient fragments is seamless over the hip line, revealing that, similar to the other combination tiles, the entire hip tile was formed as a single unit, not as two bisected and joined regular tiles.

At the first encounter, such a sophisticated shape seems difficult to create. The preserved fragments of covers are particularly confusing. On the top of the cover, the hip line is articulated by a peak at the back but transforms into a valley between the two curved surfaces at the front (Figure 9.15). On the bottom, two sets of rabbets meet from opposite sides of the hip line (Figure 9.17, right; above, Figure 3.14). Beginning with the template system for the regular tile, however, there is a simple method to create the hip tile—adding a second pair of profiled templates perpendicular to the first. The two pairs of templates are used to generate the two halves of regular tiles meeting along the diagonal of the hip (Figure 9.16).

The measurements of the preserved fragments of Protocorinthian hip tiles indicate that the two halves slope relative to one another as they would on the roof. This slope can be produced by elevating the back frames relative to the front frames. Such an arrangement has adequate clearance for the strike to pass over most of the tile without touching the surfaces on the opposite side of the hip line. At the free corner of the cover, however, the board is obstructed (Figure 9.16). There, the valley of the hip line can only be formed with the guidance of the templates at the front.

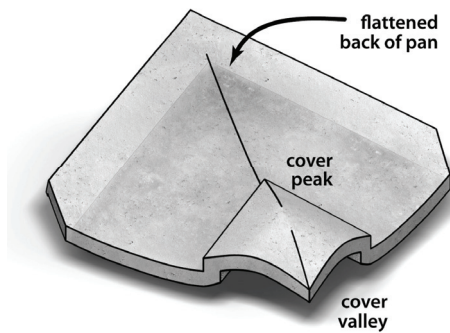


Figure 9.15 Features of the hip tile

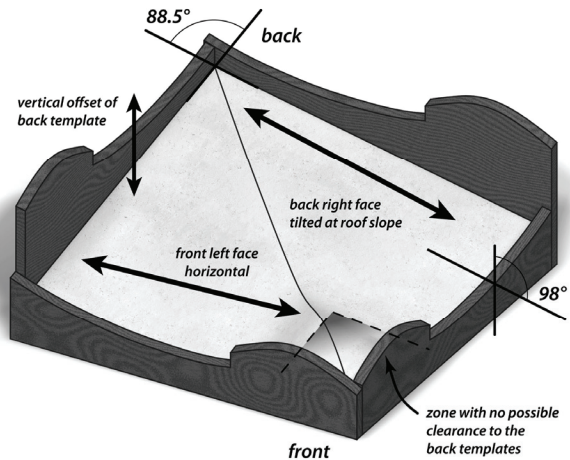


Figure 9.16 System for molding hip tiles

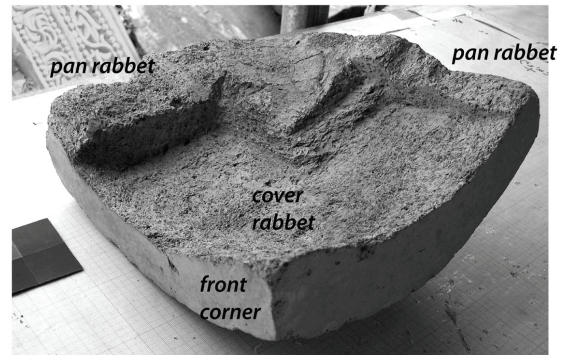
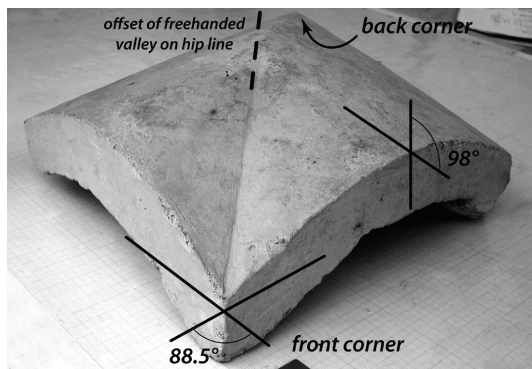


Figure 9.17 Geometry of the hip cover; top/bottom (left/right) (FC 79; 3 cm grid)

This hypothetical apparatus leads to four geometrical peculiarities of hip tiles which are also present in the ancient fragments.⁷⁰¹ First, the valley at the free end of most hip covers—the position where the strike could not reach the back template—is often significantly skewed from the true 45° line of the hip (Figure 9.17, left). As predicted by the model, this portion of the covers must have been generated freehand and, thus, would stray from the 45° hip line. Second, although the frame for shaping the tile would have been square in plan to fit the orthogonal grid of tiles installed on the roof, the hip tile also must incorporate roof slopes of about 7-8° running from both front edges up to the back sides of the pan. The upper surface of the pan is created at

⁷⁰¹ i.e., FC 79, FP 77, FP 156, FP 314, and FT 226. The geometry is predicted using the computer models designed for the figures.

the roof slope, whereas the template frame at the front face is vertical (Figure 9.16). As a result, the front face and the upper surface of the hip tile are oriented relative to one another at an angle of about 97-98° in transverse section—a right angle plus the roof slope.⁷⁰² Several hip covers preserve approximately this angle (Figure 9.17, left). Third, when the hip tile fragments are rested on a level surface, the cover appears to tilt down. At the front and back corners of the cover, the side faces appear to be oriented at approximately 88.5° degrees to one another in plan (Figure 9.17, left). These slightly acute angles are apparent only when the tile rests on the level surface. When the tile is installed at the roof slope, its sides are tilted back and appear orthogonal in plan. Fourth, the hip tile pan is almost flat at its upper end because the concave curvature at the free side of the pan is close to the angle of the pan on the opposite side of the hip line (Figure 9.15). Because the hip tiles from the Old Temple match the expectations of the hypothesized method, the Protocorinthian hip tiles almost certainly were produced in such a double-template system.⁷⁰³

The eaves hip tiles at the four corners of the roof would have been generated using a similar technique (above, Figure 3.12). The normal base mold for a hip tile would have been cut down to the horizontal along both its front edges to fit over the wood fascia, analogous to the normal eaves tiles. The upper surface of the tile can be struck with the same templates as the normal hip tiles, but the two templates at the front edges would have had peaked covers. After the tile was shaped, the front faces of the cover would have been cut back from the pan, as with the normal eaves tiles.

⁷⁰² The corresponding faces of the regular tiles are orthogonal because they were formed in horizontally oriented molds.

⁷⁰³ In order to test these predictions, I produced a replica hip tile at the University of Notre Dame between June 1 and July 11, 2005, with John Lambert. The replica has the same geometry as the ancient fragments, as predicted by the computer analysis. The results of this experiment will be published separately in *Contemporary Issues in Architectural Reconstruction* (a symposium held in conjunction with the opening of the exhibition, “The Genesis of Monumental Architecture in Greece: the Corinth Project”; to be submitted as a volume in the *Hesperia* Supplement Series), edited by R. F. Rhodes.



Figure 9.18 Ridge pan, FT 227, view from the free end; the peak line bends to the left at the attached side of the pan (i.e., at the top of the field; 3 cm scale grid)

9.E.3) *Templates for shaping ridge tiles*

As with the eaves and hip tiles, the ridge tiles can be generated by logical modifications to the regular tile mold. Similar to the hip tiles, the ridge tiles combine two symmetrical halves of regular tiles positioned at their respective slopes on the roof, but the halves meet on the longitudinal axis of the tile at a peak articulating the ridge line (below, Figure 9.21; above, Figure 3.15). The two halves of the tile are gabled, sloping up to the peak on the ridge line, which would have interfered with the striking. The gables would have prevented a straightedge from contacting both template frames at once. Theoretically, a “V”-shaped strike could have been used to shape the peak, but such a tool would be unwieldy.

In fact, three irregularities of the ancient fragments suggest a more improvisational method. First, the gabled sides of the pan do not have a consistent slope. For seven different ridge tiles, the average slope the gables is $17.9 \pm 1.8^\circ$ with a range from 14.5° to 22.8° .⁷⁰⁴ This variability is inconsistent with a “V”-shaped strike, whose angle would have been fixed. Second, the peak on the pan is not perfectly

⁷⁰⁴ From 13 different measurements at different positions along the ridge pans of FC 31, FC 61, FR 100, FR 104, FR 106, FR 117, FR 227. The gable slope calculated here is the average for both gables; first, the angle between the two gables was subtracted from 180° , and then the result was divided in half. In

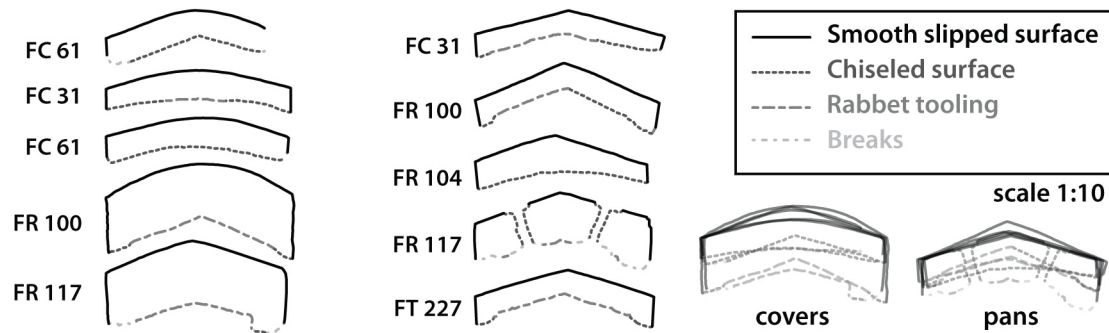


Figure 9.19 Transverse sections of covers and pans of ridge tiles

centered over the longitudinal axis. Instead, the two gables often are of different widths. In one case, the line of the peak is strongly bowed in plan (Figure 9.18). Third, the transverse profile of the cover is extremely variable. Of the nine ridge tiles whose covers are at least partially intact, five have an articulated peak along the ridge line, but four are shaped like a smooth dome (Figure 9.20).⁷⁰⁵ The transverse sections of ridge covers overlaid in Figure 9.19 deviate widely from one another, contradicting the use of a special curved strike for the cover. The ridge tiles cannot have been generated with the guidance of both templates at once. Instead, to shape the pan, the craftsmen would have drawn a straight strike at an angle against one template, forming one gable at a time. The covers are so irregular that they might have been shaped entirely freehand, although a straightedge may have been used to strike the covers with an articulated peak.

The base mold and template system must have resembled the regular tile apparatus, but the profiled templates were placed closer together (Figure 9.21, left). The templates at the short sides may also have been profiled to match the convex curvature of the cover in front and the peaked profile of the pan in back. The base

fact, the angles of the two gables of one tile often differ from one another when the tile is oriented horizontally, which means that this calculation under-represents the actual variability. The average slope is calculated here because the original stances of several tiles are uncertain.

⁷⁰⁵ i.e., peaked covers: FR 105, FR 107, FR 108, FR 117, FT 223; domed covers: FC 31, FC 61, FR 100, FT 215. The other four ridge tiles do not preserve the upper surface of the cover: FP 294, FR 104, FR 106, FT 227.

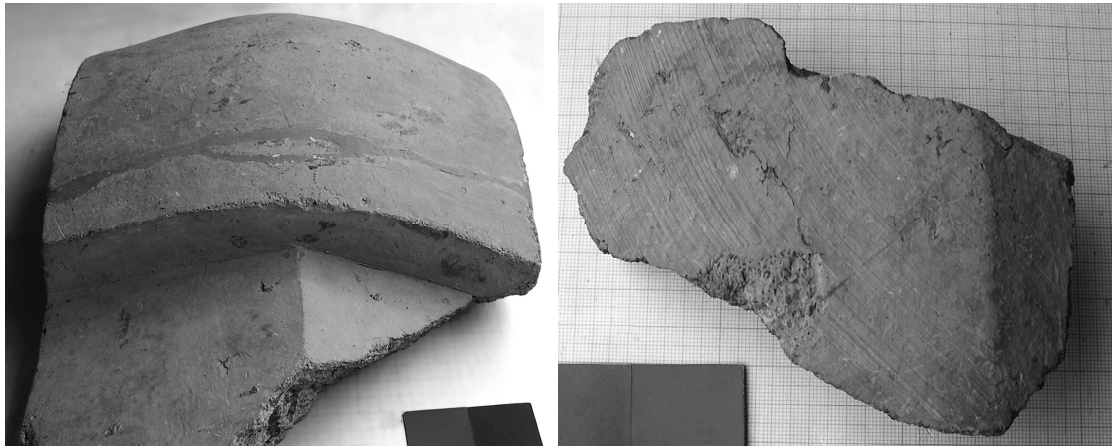


Figure 9.20 Profile of the ridge cover: *(left)* domed cover, FC 61, view from back; *(right)* peaked cover, FR 108, top (3 cm grid on both scales)

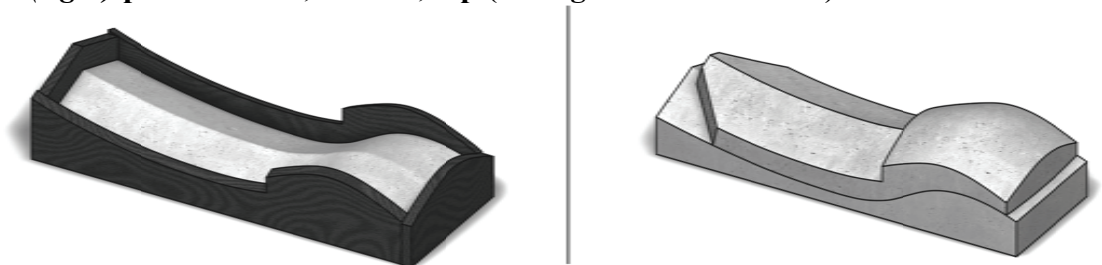


Figure 9.21 Ridge tile molding: *(left)* base mold and templates; *(right)* a tile after the primary forming with its pan bevels already cut

mold may also have been peaked, although secondary trimming on the undersides of all ridge tiles has removed most traces of the molded profile. Below the cover-pan joint of one tile, FR 117, a small segment of the molded face is preserved at the outer rim of the left pan rabbet. Although the full profile of its mold cannot be restored, at least this tile demonstrates that the front faces of the cover and pan were molded at about 7 cm high and, in most cases, later trimmed or chiseled down to a final thickness of about 2-5 cm.

9.E.1) Shaping the free cover tiles

Free covers were placed over the pans of two opposite-handed tiles meeting at the middle of the courses on all four hips of the roof (above, Figure 3.7). Covers with the profiles of regular, eaves, and ridge tiles were necessary, although only the first



Figure 9.22 Free cover tile with nail; top/bottom (*left/right*) (FC 98; 6 cm scale)

two have been identified with certainty among the remains of the Old Temple. Free cover tiles might have been produced in special, narrow molds omitting the pan. However, no such molds are necessary because a full combination can later be cut into a free cover.

The ancient fragments do not seem to have been specially molded. The underside of every free cover tile from Corinth has been cut back after firing (Figure 9.22, right). On one side, the cover rabbet has the spatulated surface markings indicating cuts into leather-hard clay. The other side, which corresponds to the thickened cover-pan joint of a combination tile, has been chiseled back after firing. This pattern suggests that free cover tiles were cut from fired, complete combination tiles by chiseling off the pans. One pan tile from the Old Temple whose cover was carefully chiseled off may have been a byproduct of the process.⁷⁰⁶ In fact, regular tiles whose pans had cracked during firing or transportation could be salvaged for use as free cover tiles.⁷⁰⁷

⁷⁰⁶ i.e., FP 336. If used for a free cover, this pan may have been immediately discarded on site or kept on reserve in the stockpile.

⁷⁰⁷ In this case, FP 336 could have been installed on the roof as a “free pan” tile. A free pan is technically unnecessary but, if paired with a free cover cut from another damaged tile, could have been installed in place of a regular tile.

However, free cover tiles were not entirely improvised on the building site. Five of the free cover tiles had nails driven through the rear overlap zone, and at least two of the nail holes clearly had been cut out before the tile was fired (Figure 9.22, left).⁷⁰⁸ Because only the free cover was nailed at its back end, the tiles with pre-cut nail holes must have been designated as free covers at the production site. Thus, the tile makers anticipated a need for free cover tiles before installing the roof on the Old Temple.

The designers still did not need to make any special molds for the free cover tiles. Because only four free eaves covers and a single free ridge cover are necessary for the full roof, to create special molds for these tiles would have wasted time. It would have been faster instead to remove the pans of five damaged combination tiles at the worksite. However, 32 to 44 regular free covers are needed for roofs 18 to 24 tiles wide, and discarding the pans of all of these tiles at the construction site would have been costly in terms of clay and kiln space. Instead of creating a special mold for the free cover tiles, which is not indicated by the tooling on the ancient fragments, the tile makers may have inserted an extra vertical board into a regular tile mold along the attached side of the cover (as above, Figure 5.7). This simple workaround would have saved a considerable quantity of clay, but excess material at the thickened cover-pan joint would have been chiseled off at the worksite. Although it cannot be proven that this was the ancient procedure, the system is plausible.

9.F) Construction of the base mold and template frames

At this point, it is possible to reconsider the materials for the tile-making apparatus. The profiled templates framing the sides of the apparatus could have been made only from wood. However, although the base molds were manufactured from

⁷⁰⁸ See below, note 744, and the accompanying discussion.

clay in the replication experiments, any workable material available during the period, such as stone or wood, appears equally possible. Moreover, stone and wood are sturdier than clay, which is a significant advantage for the whole production cycle.

In the previous chapter, it was estimated that about 1,650 tiles for a complete roof could have been produced in 72 days of intensive production. Because a mold is occupied by one tile per day, about 72 tiles would have been formed on each mold over the full course of the job. It is difficult to imagine that unfired clay molds could have survived this long, even if the upper surfaces had been fortified with lime plaster, which was the solution for the replication experiments. To solve the problem, it was hypothesized that the clay molds were fired. Although firing the kiln is an additional investment of labor, the resulting clay molds would be at least as strong as a wood mold and more resistant to fracture than limestone.

All of these materials are equally suited to forming the regular tile mold. A wooden base can be built on a profiled frame with a bedding of horizontal slats.⁷⁰⁹ The slats may be chiseled and sanded into the smooth curvature of the bottom. The same shape can be carved in stone by reference to a profiled template. As demonstrated during the replication experiments, the base mold can be struck from clay using the same technique as for the upper surface of the tiles.

However, the bases for the eaves and hip tiles are more complicated to construct from wood (above, Figure 9.14; Figure 9.15). The bottom of the eaves tile is profiled as a regular tile except where it blends into the horizontal front edge. This configuration suggests that the base was generated from a plastic material. The shape can be cut most easily from clay, although it may also be carved from a solid wood or stone base.

⁷⁰⁹ John Lambert successfully created wood molds to produce replicas of each type of tile for the Snite exhibition: see above, note 1.

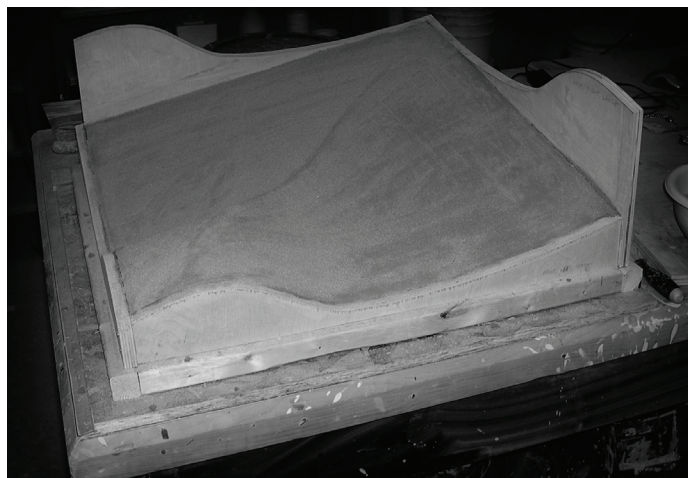


Figure 9.23 Experimental hip tile base mold⁷¹⁰

However, the hip tile base is more difficult to produce in wood or stone. Analogous to the upper surface of the hip tile, the mold takes the form of two perpendicular regular bases intersecting along the diagonal line of the hip. It is possible to construct such a base using wooden slats, but the shape is unnecessarily complicated. The subtle curvature on the underside is maintained along the complete length of the hip tile, even though the free end of the pan is virtually flat (above, Figure 9.15). If the designers had created molds from wood, it is more likely that they would have flattened the upper edge of the hip pan into a smooth plane instead of articulating the subtle double curvature which has been molded into the ancient fragments. Likewise, although possible, it is improbable that an ancient craftsman would have carved a stone base mold into this particular form. A clay base mold, however, can be struck exactly into this configuration. As with the upper surface, two pairs of template frames with the regular bottom profile guide a strike to produce the double curvature at the upper end of the pan. To test this method, a clay base mold and a replica hip tile were successfully generated (Figure 9.23).

⁷¹⁰ See above, note 703.

The strongest argument to be made for the use of fired clay over the other two materials, however, is the transverse bowing on the underside of the tiles. Because the bowing is present on the top and bottom surfaces, it is likely that both surfaces were generated using the same technique. The bowing has been demonstrated to have been an unintended effect of the shaping technique rather than drying shrinkage. Whereas the transverse bowing on a clay surface may have been due to an incomplete leveling of the surface with the strike or else an inadequately tensioned cutting wire, no such explanation is available for a carved wood or stone mold. Great care would have been taken to sand or carve out not only the exact curvature of the regular base mold but also the complex surfaces of the eaves and hip tiles. It is difficult to imagine how irregular bowing could have been introduced unintentionally into such a carefully prepared wood or stone mold.

In conclusion, fired clay is the only material that plausibly could have been used for the base molds. It is also an efficient solution. The tile makers were familiar with the technique for forming the molds, which was the same as for the tiles. No special tools or skills were necessary. Rather than adapting and enlarging some emergent mold technology—which is attested only for small figurines by the second half of the seventh century B.C.⁷¹¹—the base molds are a direct adaptation of the existing methods for producing the Protocorinthian tiles. Ultimately, the four-sided wood frames could have been derived from rectangular molds for shaping mud bricks.⁷¹² The ceramic molds were also the best suited for large-volume parallel production. Because the tiles needed to dry on the molds for a long period, 25 or more base molds would have been required to keep a small crew working full time.⁷¹³ Clay

⁷¹¹ See above, notes 344, 547.

⁷¹² Generally, see above, Chapter 4, for the survey of brick-making techniques.

⁷¹³ As demonstrated in the previous chapter. Lambert designed a two-piece wood mold to flip the tile over to dry upside-down soon after it had been shaped, which freed the mold for making another tile. However, the tile had to be supported upside-down on a specially profiled wood prop while it dried. In

is abundant in the Corinthia and easier to acquire than 25 large blocks of stone or an equivalent volume of planed wood. Carving 25 blocks of limestone or building and sanding 25 wooden bases would have required significantly more labor than shaping and firing 25 clay base molds.

9.F.1) *Dimensions of the framing system*

The surface markings on the back edges of the tile and the free edges of the pan are indirect evidence for restoring the dimensions of the original frame. The blade stroke along the back edge probably was intended to cut the tile loose from the frame. Another possibility is that the tiles were larger when molded and cut down to size after the frames had been removed. However, the total depth is very consistent on eight preserved tiles from Corinth (average transverse measurement: 64.89 cm, $\sigma = 0.22$ cm, $CV = 0.3\%$),⁷¹⁴ which suggests that the overall dimensions of the tile were fixed by the template frame rather than cut freehand. The minor variations in the observed transverse dimensions may have been introduced by the blade stroke, the pressure from applying slip after the frames had been removed, or differences in total drying shrinkage due to variation in the amount of water initially in the paste. Although the front edge of the tile was reworked when it was coated with slip, the consistency of the overall depth measurements of the tiles indicates that this dimension was fixed by the position of the front and back frames.⁷¹⁵

addition to being unnecessarily complicated, the system would have required identical copies of 20 to 25 props for upside-down tiles to dry, which makes it less efficient than simply leaving the tiles to dry on the base molds. The ancient fragments preserve no surface markings to indicate that they were turned upside-down before they had dried leather hard. See above, note 709.

⁷¹⁴ i.e., FP 76, FP 110, FP 155, FP 157, FP 158, FT 210, FT 224, FT 228. CV is the coefficient of variation; σ is the standard deviation of the sample.

⁷¹⁵ It is possible that the tiles were cut to a carefully measured transverse dimension. However, this procedure would have been difficult. Due to the curvature of the tile, a straightedge cannot have been used to guide the cut.

The total length dimensions are more variable. The full length of fourteen regular and free cover tiles is the most consistent (average longitudinal measurement: 24.96 cm, $\sigma = 0.24$ cm, CV = 1.0%).⁷¹⁶ This variability is low enough to indicate that the free side of the cover probably was formed directly against the frame. Then the full length of the cover would have been fixed by the template frame, which incorporated both sides of the cover. However, the length of the pan is more variable on the four preserved examples (average longitudinal measurement: 42.10 cm, $\sigma = 1.89$ cm, CV = 4.5%).⁷¹⁷ This variability in length together with the inclination of the face and the surface markings indicate that the free edge of the pan was cut back immediately after the primary forming rather than formed up against the vertical frame.

As a result, the overall dimensions of the regular Protocorinthian tiles appear to have been fixed by the template frame on the free side of the cover, the front, and the back. The free side of the pan must have been molded at a larger dimension before it was cut back. Disregarding drying shrinkage for the moment, the front and back templates would have been separated by approximately the depth of the tiles—perhaps 65.0 cm to allow for a small amount of clay removed by any cutting to separate the tile from the frame. The full length of the base mold may be restored for the eaves tiles, which preserve some traces of the frame on the free face of the pan near the front. Only one eaves tile, FT 211, preserves this full length for the pan, where it measures 45.4 cm.⁷¹⁸ Because the base mold for the eaves tiles is derived directly from the mold for regular tiles, it is likely that both tile molds were approximately the same size.⁷¹⁹

⁷¹⁶ i.e., FC 29, FC 62, FC 78, FC 96, FC 98, FP 155, FP 157, FP 158, FP 164, FT 210, FT 224, FP 325, FP 327, FP 333.

⁷¹⁷ i.e., FP 76, FP 155, FT 210, FT 224. The full lengths of the pans of only five regular tiles have been restored, and the fifth tile, FT 228, has been excluded from the list because the free end of its pan was chiseled back after firing.

⁷¹⁸ Although most of the pan of FT 209 also has been restored, the free side of the pan appears to have been cut back after molding.

⁷¹⁹ However, FT 209 and FT 211, the two eaves tiles with a complete transverse dimension, measure 65.5 and 65.8 cm, respectively, which is 0.6-0.9 cm greater than the average for the regular tiles and

Including the dimension of the cover, the length and depth of the inner edges of the frame would have been 70.5 x 65.0 cm, excluding shrinkage. The average shrinkage rate of the clay is unknown, although it probably was higher than the rates observed during the replication experiments because the ancient tiles appear to have been formed when the paste was wetter. Assuming 5% total shrinkage, the original mold would have been approximately 74.2 x 68.4 cm.

9.F.2) *The primary forming of Protocorinthian tiles from other roofs*

The procedures for manufacturing all Protocorinthian tiles would have resembled the one outlined above for the roof of the Old Temple. Although fewer have been fully restored, the Isthmia tiles published by Broneer have virtually identical profiles and dimensions. For example, the full length preserved on nine regular cover tiles is statistically indistinguishable from the dimension at Corinth (average longitudinal measurement: 24.93 cm, $\sigma = 0.30$ cm).⁷²⁰ The same is true of the length of the pan (average of four measurements: 42.00 cm, $\sigma = 0.19$ cm) and the overall depth (average of four transverse measurements: 65.10 cm, $\sigma = 0.19$ cm).⁷²¹ The profiles of the covers and pans at the two sites are identical, although the covers of the Isthmia tiles are oriented slightly lower relative to the pan in comparison to the covers and pans from the Old Temple. The surface markings on the back faces, the underside, and the free ends of the pans at Isthmia are similar to those described from Corinth. The raised peaks on the pans of the Isthmia eaves tile were only a secondary addition after the upper surface had been struck (see below). Thus, the Corinth and Isthmia tiles

well outside the standard error. Consequently, either the eaves tiles were produced in slightly deeper frames, or else the back sides of the regular tiles were cut down by about a centimeter.

⁷²⁰ i.e., Isthmia Museum IT 108, IT 109, IT 121, IT 193, IT 212, IT 232, IT 238, IT 310, IT 376; also see Broneer 1971, p. 51 (AT 1, AT 4, AT 5).

⁷²¹ i.e., for both dimensions, IT 310, IT 311, IT 312, IT 376; also see Broneer 1971, p. 51 (AT 1-4).

were produced using the same primary forming techniques.⁷²² The tiles of both roofs were designed to the same dimensions, although the small variations in the profiles reveal that the tile makers at Isthmia created a new set of template frames for this second project.

The Protocorinthian tiles from Delphi differ slightly from those of the Corinthia in profile and dimensions. Three covers from one roof preserve a significantly larger full length (average longitudinal measurement: 25.70 cm).⁷²³ The profiles are slightly different as well. Clearly, the tiles were generated using a different set of molds and templates, but the primary forming sequence would not have changed.

9.G) Secondary forming sequence and surface modifications

Only a few modifications to the preliminary hypothesis for the secondary forming sequence and the surface finishing are warranted. The notches, corner bevels, and rabbets are the most common secondary features; the nail holes cut into two free cover tiles before firing technically are secondary features but will be discussed with the post-firing modifications. Slip, paint, and setting guidelines are the only surface modifications for most tiles.

The notch and corner bevels were cut out with a spatula or a knife. The tooling on the corner bevels of some tiles indicates that they often were cut after the tile had dried leather hard. It is unclear whether the craftsmen waited to cut the bevels until these tiles had dried, or whether they were only retooling precut surfaces. The delay

⁷²² The same must be assumed for the three fragments of other Protocorinthian roofs from the Sanctuary of Demeter and Kore and the Sanctuary of Hera at Perachora, although too little is preserved of these tiles to warrant a detailed comparison.

⁷²³ i.e., Delphi museum 21635 (AR 6), 21637 (AR 1), 21646 (AR 15+16): Le Roy 1967, pp. 21-23; all three are grouped together in his Series 3. It is unclear whether the overall design units for the Delphi roof were different, because only the measurements of the complete length and depth of the tiles as installed on the roof are significant for restoring this module.

would have been inefficient, because the bevels are most easily cut right after the primary forming, when the clay is still soft. Because the tiles had shrunk to approximately their final size when the clay became stiff leather hard, the craftsmen may have waited until then to cut or adjust the corner bevels at their final dimensions. If this had been the case, however, the adjustments were unsuccessful. At least part of almost every bevel was re-cut with a chisel during installation on the roof.

9.G.1) Cutting the underside rabbets

Irregular rabbeted shelves were hacked into the underside after the clay had dried leather hard (as above, Figure 5.9). The craftsmen could survey the position of the inside edges of the rabbets by cutting guidelines. As discovered during the replication experiments, however, the rabbets were difficult to cut to a consistent profile because there is no convenient point of reference to measure the depth and angle of each rabbet (Figure 9.24). As a result, the cover and pan rabbets are the most variable elements in the longitudinal and transverse sections of the tiles (above, Figure 9.11).

Trimming the rabbets was probably the most inefficient component of the entire manufacturing. Whereas the notch and corner bevels were formed quickly during the replication experiments, shaping the cover rabbet occupied about 15% of the total time for shaping a tile.⁷²⁴ Moreover, during installation on the roof, the rabbets were the most heavily chiseled area. This raises the question of why the rabbets were not directly molded into the base. Not only would this have shortened the production times, but also it would have standardized the lower joint faces of the tiles, greatly facilitating installation.

⁷²⁴ See above, Table 6.6, Table 8.1.



Figure 9.24 Raised lip (*left*) along the free edge of the rabbet, FP 329 (front edge at bottom of field; 5 cm grid)

The reason that the rabbets were cut out later was probably connected to the rapid drying of the tiles on the base mold. The tile must dry leather hard before it can be removed. In as little as six hours, the tile shrinks approximately 3-6% while it rests on the inert base mold, subjecting the tile to considerable strain. Even the smooth profile on the bottom of the regular tile is problematic. Most of the tile is able to contract unimpeded on the base mold, but the cover tends to be caught against the descending curve at its free end (above, Figure 3.8; Figure 6.12). The thickened cover-pan joint resists this strain, but two of the earlier replica tiles split at the attached end of the pan as they dried and contracted. Rabbets molded into the base probably would have caused many tiles to split apart. First, the tile would have been thinner at the rabbets and less able to withstand strain. Second, the sudden changes in thickness at the inside edges of the rabbets would require a sharp transition in the mold, raising the chances that the tile would pull apart against a raised area on the base. Thus, the rabbets probably had to be cut out late in the forming process to prevent splitting. This problem appears to have been common. None of the Protocorinthian tiles has a

molded rabbet on the underside, and, in Archaic practice in general, shelves in the equivalent positions were cut out rather than molded directly into the undersides of cover or pan tiles.

The rabbeting systems of the roofs at Corinth, Isthmia, and Delphi appear to have been refined gradually.⁷²⁵ First, a raised lip running along the outer edges provided the necessary flexibility for the placement of the tile (above, Figure 9.24). The function of the lip would have been analogous to band anathyrosis in later masonry. The tile makers could hastily cut out an uneven surface at the interior of the rabbet as long as they left a narrow strip of material along the edges. The narrow lip could have been trimmed to fit the adjacent tile during installation with relative ease because the material behind the rim had already been removed before firing. The tiles from the two Protocorinthian roofs at Corinth and Isthmia have relatively low lips on their rabbets, although in most cases the entire lip was later chiseled away. Some of the Delphi tiles, however, have a very tall, thick lip (above, Figure 3.10). This refinement, which would have saved time during the adjustments for installation, suggests that at least one Protocorinthian roof at Delphi post-dated the construction of the Corinth and Isthmia temples.

The second refinement is evident from the pan rabbet. At Corinth, only the cover rabbet was cut when the clay was leather hard. The pan rabbets of the regular and hip tiles were never trimmed before firing. Because the pan rabbet was essential for normal interlocking on the roof, the builders were instead forced to chisel out the entire shelf at the construction site. However, this omission appears to have been a deliberate choice. The narrow, horizontal pan rabbets of the eaves tiles from Corinth were cut first before firing. The entire underside of the ridge tiles, including both

⁷²⁵ Too little is preserved of the three Protocorinthian tiles from Perachora and the Demeter and Kore sanctuary to determine how their rabbets were produced.

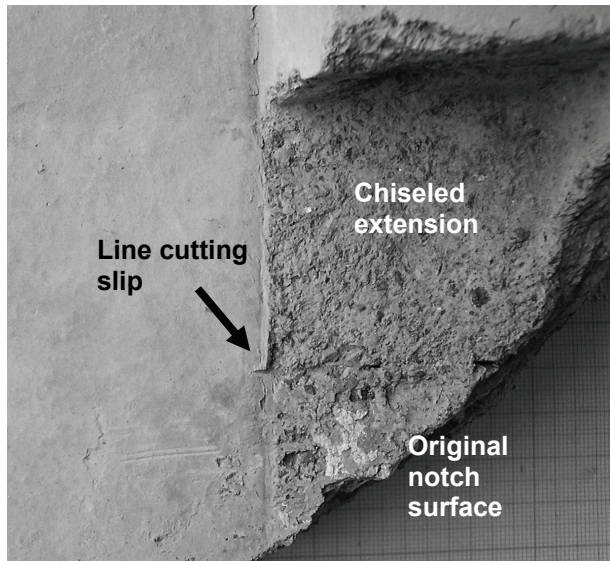
cover and pan rabbets, was tooled when the clay was leather hard. Whether or not the designers of the Corinth tiles believed the omission would be advantageous, the producers of the tiles from Isthmia and Delphi chose to cut the pan rabbets into the regular and hip tiles at the same tiles as the cover rabbets—that is, when the clay was leather hard. Chiseling is laborious and risks destroying the whole tile. Because the pre-cut pan rabbets at Isthmia and Delphi reduce the amount of trimming required at the construction site, they represent an improvement on the system for the Old Temple. In conclusion, the approaches to tooling the rabbets are consistent with a chronological progression from Corinth to Isthmia and Isthmia to Delphi. This order is supported by other evidence from Corinth and Isthmia, and the progression provides new evidence for the relative date of the Delphi roof.⁷²⁶

9.G.2) *Surface modifications*

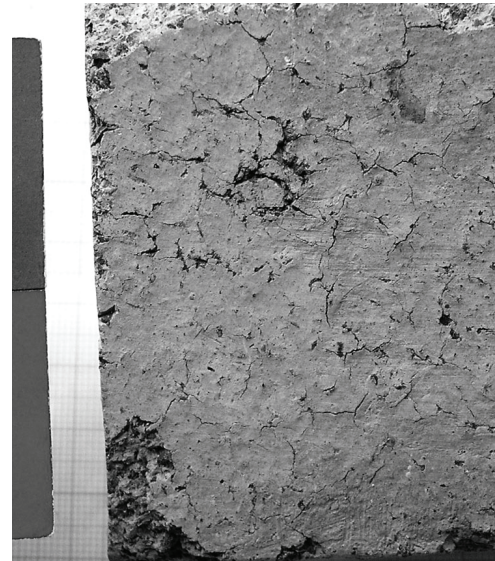
The general discussion in earlier sections of the fine slip on the visible faces of the Protocorinthian tiles may be elaborated.

For the majority of the tiles, the slip was applied after the notch had been cut. In addition to confirming this sequence of operations, the thick wads of excess slip wiped over the face of the notch of one tile, FP 330, show that the slip was relatively thick and viscous when it was applied, having a cream-like consistency (above, Figure 5.11). On the other hand, the notch of one tile at Corinth, FP 342, is certain to have been cut into the tile after it had been slipped (Figure 9.25). The notch was cut in two phases which must be explained to interpret the photograph correctly. At first, the craftsmen cut an abnormally shallow notch. The tip of the blade reached slightly farther than necessary, cutting a straight line into the notch floor that is visible in (Figure 9.25). Second, when the tile was installed on the roof, the notch was extended

⁷²⁶ The date of the Delphi roof was conjectural: Winter 1993, p. 17; and above, note 107.



**Figure 9.25 Top view of the notch, FP 342
(back at bottom of field)**



**Figure 9.26 Cracked slip (FC 114; 3
cm scale grid at left)**

to its present dimensions by chiseling. Thus, only the surfaces of the notch behind the blade line are relevant for determining the pre-firing sequence of this tile. Although most of the back side of the notch is broken away, the slip of the pan clearly bends up along the adjacent edge. This suggests that the slip was originally applied against the vertical attached face of the cover, whereas the notch was cut afterwards. The order of events is confirmed by the line from cutting the original front face of the notch. The line extends a short distance into the pan and cuts the slip. Consequently, at least FP 342 was slipped before its notch was cut, although the tile is exceptional.

The slip was a remarkably good fit for the tempered paste. Only rarely did it crack by shrinking at a different rate than the paste (Figure 9.26). On occasion, very small seams opened over the sharply defined cusp where the attached side of the pan meets the lower edge of the cover (Figure 9.27). Spalls are the most common defect. The finished surfaces often have one or two large cavities opened by a calcareous nodule a centimeter or more across (Figure 9.28). Otherwise, most of the upper surfaces have a smooth polish. The side faces are comparatively rough. In some cases, the layers of slip have not been evened to a consistent thickness, and frequently the



Figure 9.27 Slip wiped over the rough surface of the attached face of the cover; cracking at the attachment with the pan (FC 62; 6 cm scale at bottom of field)

pocked undersurfaces show through the slip (Figure 9.27). The lack of polish on the sides is consistent with the base mold having been installed low to the ground. As discovered during the replication experiments, it is difficult to draw a strike over the 70 x 75 cm frame without standing over the mold. Protocorinthian tiles could not have been shaped effectively if their molds had been elevated on tables similar to those used by modern tile makers. Because the slip must have been applied before removing the tile from the base mold, the Protocorinthian tile makers would have been forced to polish the slip while the tile was near the ground. They could have worked the top surface without difficulty, but they would have been forced to stoop at an uncomfortable angle to see the result of the polishing on the sides.

In contrast to the buff slip, the dark paint on the tiles at Corinth always cracked (for example, above, Figure 5.13). It is unclear whether the cracking was affected by firing or was entirely due to a poor fit with the paste of the tile. The paint has splotches of red or has turned entirely reddish-brown, indicating problems with the paint mixture or an imperfect control of the kiln atmosphere.⁷²⁷

⁷²⁷ See above, notes 308, 309 and the discussion in Chapter 6, p. 146f.



Figure 9.28 Damage from spalling on the pan (FT 228; 3 cm scale grid at left)

The upper surface of the tiles from Isthmia has not always been completely slipped. On several tiles, an uneven strip several centimeters wide running along the back edge has been reserved.⁷²⁸ The unslipped edges lie inside the transverse overlap zone, where they would have been concealed below neighboring tiles. This variation could be explained as a minor improvement over the system for the Old Temple. At Isthmia, the omission of slip along the concealed edges would have saved a small amount of time without affecting the final appearance of the roof.

The triangular wedge on the pan of the eaves tiles at Isthmia was added after the primary forming sequence had concluded (Figure 9.29; and above, Figure 3.12).⁷²⁹ Unlike the normal fabric, the wedge was built entirely out of fine, untempered clay that resembles the slip. The wedges are not consistently formed and, thus, appear to have been shaped freehand. To finish the wedge, its front edge was trimmed back to a straight plane. Clearly, the wedges were added after the primary forming had concluded, and at least some examples were slipped afterwards.

The setting guidelines that mark the intended lateral and transverse overlaps were cut after the clay had dried leather hard. Some guidelines were cut into the black

⁷²⁸ Although most of these surfaces are reworked, traces of the longitudinal striations left by the striking procedure are sometimes visible.

⁷²⁹ For a list of examples, see Broneer 1971, p. 52 (AT 18 – AT 20), pp. 45-46 figs. 60-61. Hemans counted 33 peaks during his recent study of the Isthmia roof: Hemans 1989, p. 260 table A.



Figure 9.29 Front view of the wedge added to the eaves pans at Isthmia; untempered clay is exposed in the break at the tip—compare to the tempered clay exposed in the break at the left (IT 219; Broneer 1971, AT 20, p. 52, fig. 60; 5 cm grid)

slip and, thus, must have been one of the last modifications to the tile before firing. In a few cases, an incised line is preserved along the edges of the corner bevels, as if the position of the bevels had been surveyed only after these tiles had dried.⁷³⁰ Although the consistency of the overall transverse and longitudinal measurements of the tiles at Corinth and Isthmia indicates that they were molded to one set of dimensions, the tile makers could have eliminated even a small variation from drying shrinkage by waiting to incise the setting guidelines until the end of the forming sequence. Furthermore, because the tile had shrunk to more or less its final dimensions at that stage, the guidelines could have been marked using the same building units at the construction site. No compensation for shrinkage would have been necessary. Of course, as indicated by the weathering lines and the chiseling, the builders were unable to set many tiles at exactly the intended module, but the guidelines would have generally facilitated installation of the roof.

⁷³⁰ e.g., FC 115.

9.H) Post-firing modifications for setting the tiles

New tests are required before the discussion of the firing process in Chapters 6 and 8 can be continued. However, several post-firing surface features show how the roof of the Old Temple was installed.

Every tile appears to have been retooled to fit exactly in place on the roof. The builders used narrow chisels for most of the reworking. The chiseling is concentrated on the overlap zones. Most frequently, the builders adjusted the notch, the corner bevels, the outer edges of both rabbets, and the upper surface of the pan along its free edges. Every type of tile was chiseled, and the pan rabbet at the front of the eaves tile was polished afterwards to fit over a straight wood fascia.

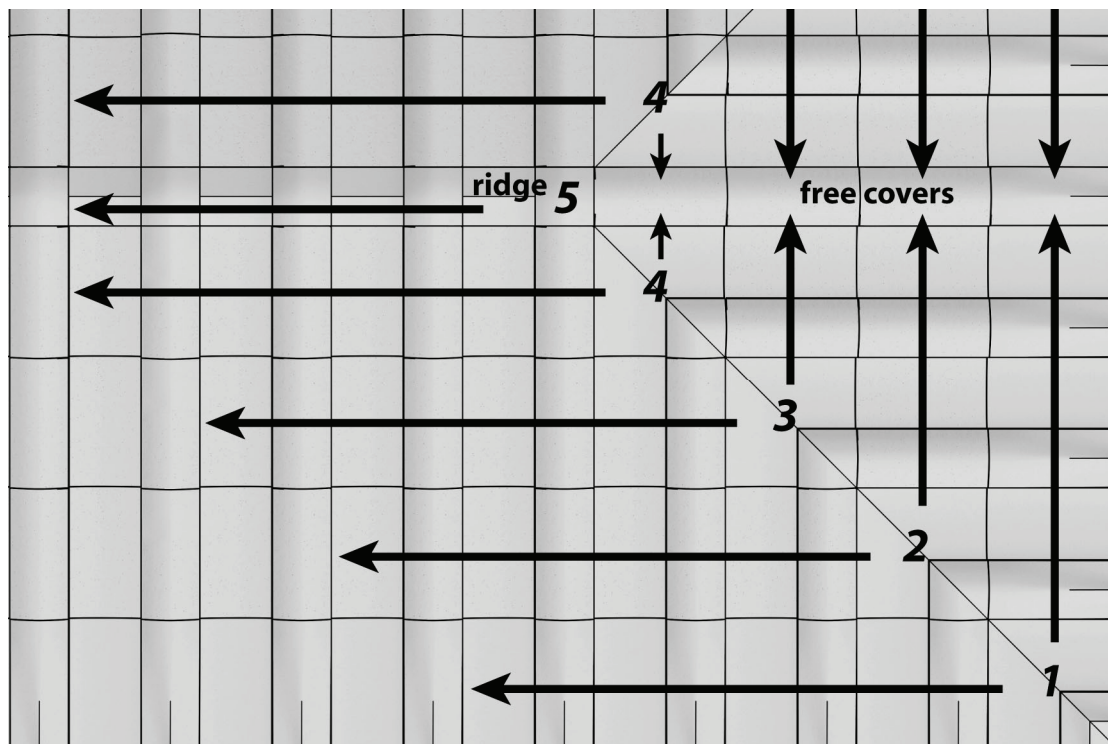
Cream-colored patches of what is probably a lime mortar adhere to the joint faces of several tiles from the Old Temple.⁷³¹ The mortar is better preserved at Isthmia, where it usually appears on the faces of the rabbets. On the pan rabbet of the eaves tiles, patches of mortar with a small raised lip mark the position of the wood fascia set one or two centimeters behind the front face of the tile.⁷³² Consequently, the front edge of the pan rabbet, which slopes down from its inner edge, would have formed a shallow drip, diverting some rainwater away from the recessed fascia (as above, Figure 3.7). As preserved, the patches of mortar are no more than two millimeters thick. After the rabbets were chiseled, it appears that the seams were filled with mortar to create a waterproof seal. The practice is standard in modern roofing.

9.H.1) Installation sequence

The builders installed and trimmed the tiles in a predictable order. The tiles were designed to be laid in horizontal rows starting with the hip tiles (Figure 9.30). In

⁷³¹ See above, note 312.

⁷³² As first noted by Hemans 1989, p. 262. No mortar remains on the tiles from the Demeter and Kore sanctuary, Delphi, or Perachora.



**Figure 9.30 Setting order of the Protocorinthian tiles on the roof
(eaves hip tile at the bottom right corner)**

each row, opposite-handed tiles were laid on both sides of the hip line. From the four hips, as many as eight horizontal rows of tiles could have been installed simultaneously. The series of opposite-handed tiles met near the center of each hip, where the free cover was laid to finish the horizontal row. The builders set the first horizontal row at the eaves and proceeded, row by row, up to the ridge line. The row of narrow ridge tiles was the last installed. The builders probably would have completed each horizontal row before beginning to lay the next.

Each regular tile was placed in contact with at least three other tiles already in position. The free side of its cover fit over the pan of the tile previously laid in horizontal row. Its pan rabbet fit over the pan and notch of the tile below, and its pan bevel abutted the cover bevel of the diagonally adjacent tile in the row below (above, Figure 3.7, bottom left). All three of these features—the two rabbets and the pan bevel—must have been trimmed before the tile was fixed in position.

Before chiseling, the builders probably tried to set the tile in place in order to identify mismatches. The profiles were complicated, and a substantial quantity of material had to be removed from both rabbets. In particular, the entire pan rabbet was cut at the construction site of the Old Temple. The builders must have turned the tile upside-down for this chiseling, resetting the tile repeatedly until satisfied with the fit. The work would have been difficult and time consuming. The replication experiments determined that chiseling the rabbets was possible only if the tile was treated gently to keep it from fracturing. Because hoisting the tile up and down from the roof for each adjustment would have been risky and inefficient, the builders must have chiseled most the tiles up on the roof. After completing the trimming, they wiped a small quantity of mortar over the edges of the rabbet and fixed the tile in place.

The tile would be altered again. The upper surface of the pan often has been retooled along its free edge to accommodate the cover rabbet of the next tile in horizontal row. Every eaves pan preserving this area was cut back on its free edge, probably to avoid trimming the adjacent cover which, for the eaves tiles, is particularly prone to breaking (above, Figure 3.11). The notch and the cover bevel were retooled last. Misalignments at the back of the tile could have become apparent only when the builders had completed the horizontal row and were setting the tile above (Figure 9.30). If the tile were removed to re-cut the free edge of the pan, the mortar sealing the joints would have been broken. At the time the notch and cover bevel were trimmed, the tile would have been locked in place by the next tile in horizontal row. The builders almost certainly chiseled all of these features while the tile was in position.

If the tiles were laid directly on the rafters, a moveable wooden platform would have been required to support the workmen as they tailored the tiles on the roof. However, a solid decking over the rafters would have made the job much easier, and

the tiles might have been securely supported on a bed of unfired clay.⁷³³ The free edge of the pan, the notch, and the corner bevel must have been chiseled delicately because the tile was already in position. With open rafters, the lower end of the tile was supported on its rabbets alone and would have been prone to cracking with each blow of the chisel. A clay bed under the pan, however, would have absorbed much of the shock. Although the evidence is inconclusive, the extensive chiseling on the Protocorinthian tiles suggests a system of battens, sheathing, and clay was installed above the rafters.

9.H.2) *Spacing units*

It is possible to determine the spacing units of the tiles as they had been installed. The exposed length of the regular tiles on one end of the building must equal the exposed depth of the regular tiles at the other side of the hip, because both groups of regular tiles must be spaced evenly to interlock with the hip tiles (above, Figure 9.30). With orthogonal walls below, the length and depth spacings of the tiles could have been unequal only if the tiles on the fronts and flanks of the building were differently spaced, such that their length and depth measurements were reversed over the hip line.

An unequal spacing of the front and the flank may be excluded for two reasons. First, the hip tiles have square covers, meaning the hip line runs at 45° to the tiles in plan. Unequal units would require an oblique angle at the hip line. Second, the regular tiles preserve only a single, narrow range of measurements for both the

⁷³³ There is no evidence for such a clay bedding preserved on the Old Temple tiles, despite Robinson's report of clay adhering to the undersides of some tiles: see above, note 312. Beddings for some tile roofs are attested by the Classical period, and doubtless many Archaic tiled roofs had clay beddings. The strong curvature on the underside of the Protocorinthian tiles is not well suited for setting on a clay bed. From my experience working with these tiles, however, I suspect they are too fragile to have been unsupported—the pans would crack under the weight of a workman repairing the roof.

exposed length and depth spacings. As described above, the transverse dimension of the tiles was consistently molded, shrinking on average to about 64.9 cm,⁷³⁴ whereas the total longitudinal dimension was more variable, shrinking to about 67.1 cm.⁷³⁵ However, the spacing units of the roof are not the overall measurements of the tile, but rather the distances across the tile exposed beyond its overlapping neighbors. The transverse and lateral overlaps must be subtracted from the overall measurements of the tiles to determine these exposed dimensions. The average actual transverse overlap on the roof indicated by the weathering lines is 9.2 cm ($\sigma = 1.3$ cm),⁷³⁶ whereas the average intended transverse overlap indicated by the incised lines is 9.4 cm ($\sigma = 1.5$ cm).⁷³⁷ The average actual lateral overlap on the roof is 11.6 cm ($\sigma = 1.7$ cm),⁷³⁸ whereas the corresponding intended overlap is 12.0 cm ($\sigma = 1.6$ cm).⁷³⁹ Consequently, the average exposed area of the tiles has a length and width of 55.5 x 55.7 cm (longitudinal by transverse). The average intended exposed dimensions are 55.0 x 55.5 cm (length by width). Although less numerous, the mended regular tiles which preserve the full exposed dimensions correspond to these averages: actual exposure, 55.1 x 55.4 cm,⁷⁴⁰ and intended exposure, 56.1 x 55.0 cm (longitudinal by transverse).⁷⁴¹ Too few tiles are preserved to determine the building unit precisely. However, the exposed lengths and widths of the tiles as installed on the roof must

⁷³⁴ See above, note 714.

⁷³⁵ i.e., the total of the cover (25.0 cm) and pan (42.1 cm) lengths. See above, notes 716, 717.

⁷³⁶ For 17 regular and free cover tiles at Corinth. Eaves tiles are excluded because their overall transverse measurement appears to have been slightly greater than that of the other tiles, although some eaves tiles may have inadvertently been included in this count because the back edges of eaves tiles are indistinguishable from regular tiles. The average dimension at Isthmia is slightly lower, within one standard deviation of the Corinth measurements.

⁷³⁷ For 16 regular and free cover tiles at Corinth. The average dimension at Isthmia is slightly lower, within one standard deviation of the Corinth measurements.

⁷³⁸ For 26 tiles at Corinth. The lateral overlap measurements of regular, eaves, hip, and ridge tiles are similar. The average dimension from Isthmia is similar.

⁷³⁹ For 18 regular and free cover tiles at Corinth. The average dimension at Isthmia is slightly lower, within one standard deviation of the Corinth measurements.

⁷⁴⁰ For 5 longitudinal measurements and 7 transverse measurements of regular tiles at Corinth.

⁷⁴¹ For 5 longitudinal measurements and 6 transverse measurements of regular tiles at Corinth.

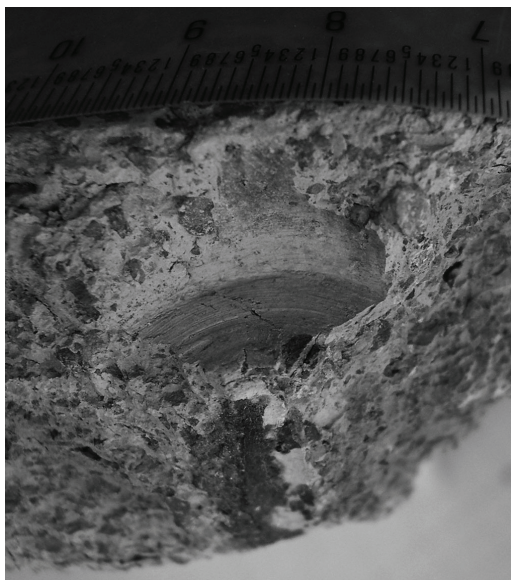


Figure 9.31 Round countersink and nail shaft with iron corrosion; free cover FC 109 (ruler at top of field) **Figure 9.32 Ridge tile with nail holes and countersinks drilled after firing (FR 117; 3 cm scale grid at bottom left)**

have fallen within a broad 95% confidence interval of about 52.5-58.5 cm.⁷⁴² The entire roof could have been measured out in square modules equal to one tile minus the overlap, a distance of approximately 56 cm.⁷⁴³

9.H.1) *Tiles nailed in position*

Five free covers at Corinth and three ridge tiles from both Corinth and Isthmia were nailed in position. Whereas all of the nail holes in the ridge tiles appear to have been drilled after firing, the holes in the free covers may all have been drilled before firing. The nail holes were always countersunk in order to conceal the nail heads. Two iron nails are partially preserved, iron corrosion remains on the surfaces of three other holes, and one lead shaft is preserved in a ridge tile from Isthmia.⁷⁴⁴

⁷⁴² However, the exposed transverse dimension would have been slightly longer as measured on the surface of the tile, because the tile is sloped on the transverse when installed on the roof.

⁷⁴³ Rhodes described this phenomenon as a “design square”: Rhodes 1984, p. 97.

⁷⁴⁴ i.e., Corinth free covers: FC 96 (iron shank intact), FC 98 (intact nail head and shank in countersink), FC 108 (iron traces), FC 109 (iron corrosion). Isthmia ridge tiles: IT 228 (lead shank), IT 373 (iron traces). No traces of metal remain on FC 107 (free cover) or FR 117 (ridge), both from Corinth.

The nail holes on the free cover tiles were not consistently prepared. The surface markings and coloration indicate that two of the tiles had been countersunk before firing. The full extent of the shaft is exposed by the break in FC 109 (Figure 9.31). In this case, the countersink and the narrow hole for the nail shaft had been drilled while the clay was relatively damp. The drill left concentric circular grooves on the bottom face of the countersink, and damp clay was wiped against the sides of the nail hole. The lower shaft does not appear to be perfectly centered in the countersink, indicating that the two features were cut separately—first the countersink, then the shaft. Although the nail head still preserved in FC 98 is round, the countersink cut into the upper surface of the tile before firing is rectangular (see above, Figure 9.22). According to their dimensions, both countersinks were cut by an instrument whose blade was 2.4 cm wide. Thus, the tile makers may have cut the holes with the same spatula used for the other pre-firing trimming. It is unclear whether FC 96 or FC 108 were drilled before or after firing, but neither has a precut countersink. Instead, the upper surfaces around the nails were chiseled down after firing. The off-center hole in FC 107 may also have been punched before firing, although it has no countersink. Thus, every free cover from Corinth probably was secured with a nail, and a majority of the nail holes appears to have been cut at the production site. In contrast, the free covers at Isthmia do not appear to have been nailed into position at all,⁷⁴⁵ perhaps because they were found to be unnecessary for the Old Temple.

The three ridge tiles from Corinth and Isthmia were drilled after firing, and rounded countersinks were chiseled in the upper surface. The rotary drill exposed the reddened interior of FR 117, which consequently must already have been fired (Figure 9.32). Both holes were drilled twice—first with a narrow drill and second with a wider drill

⁷⁴⁵ Hemans 1989, p. 262. I was able to identify only one free cover tile at Isthmia, IT 357: Broneer 1971, p. 51, where it is listed with his regular tiles.

1.2 cm in diameter that obliterated most traces of the first hole. At least one tile, IT 373, has four holes drilled into the pan—a pair near the attachment to the cover and another near the back. Because the other ridge tiles preserve only the attached end of the pan, each may have been secured by four nails. However, most ridge tiles were not nailed in position at all. The nails appear to have been an afterthought, perhaps added in reaction to damage by a storm. The ridge tiles at the ends and the center of the row may have been anchored with nails because these would have been more likely to shift out of position. The free cover of the ridge, a necessary type which has not been identified at any site, was the last tile installed on the roof. Because no other tiles overlapped it, the free ridge cover must have been secured with a nail at Corinth and Isthmia.

9.H.1) *Eaves combination tiles used as regular tiles*

An unusual type is found among the tiles from Old Temple at Corinth and the Temple of Poseidon at Isthmia. Although the tiles were cut to fit in the position of a regular tile, the cover has been formed as an eaves tile.⁷⁴⁶

Two features of these tiles are diagnostic for eaves tiles: the upper edge of the cover is slightly concave, and its front face is set back about one centimeter from that of the pan (Figure 9.33). The undersides are heavily chiseled, also consistent with re-cutting an eaves tile. Because the front of an eaves pan is much thicker, the excess material must be chiseled back to the profile of a regular pan rabbet. The chiseling is unusually well sorted. If the builders did the trimming on the ground instead of the roof, they could have taken greater care with the re-cut eaves tiles than the others.

⁷⁴⁶ Corinth: FC 83, FC 114, FT 218, FT 225, FP 310; Isthmia: IT 372. Also see Broneer 1971, p. 52 (AT 13), who noted but was unable to explain the secondary tooling on the underside.

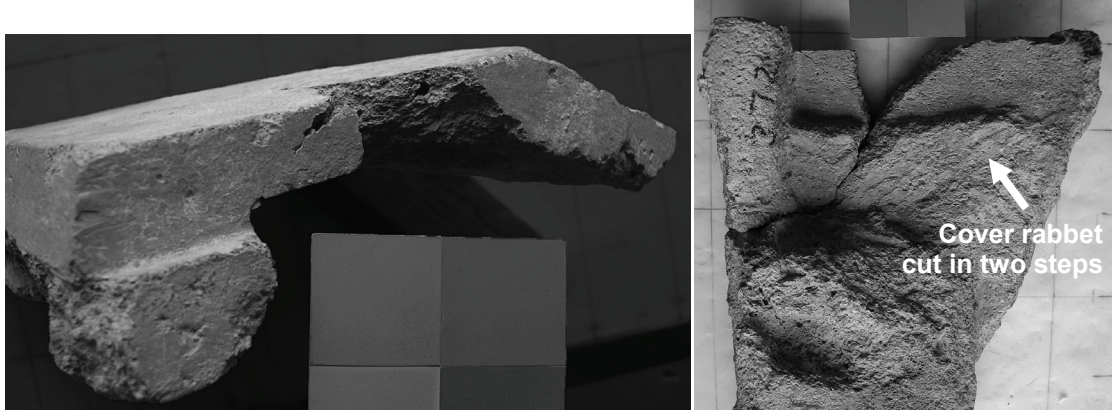


Figure 9.33 Right-handed eaves tile re-cut into a regular tile (Isthmia IT 372; Broneer 1971, AT 13): (left) front face (3 cm scale card grid); (right) bottom view (front edge at top of field, pan rabbet at left; 5 cm background grid)

Because only the front attached corner of the cover is diagnostic, the five re-cut eaves tiles identified among the remains of the Old Temple roof suggest that this practice was relatively common.⁷⁴⁷ Many explanations are possible. The tile makers must have created many more eaves tiles than necessary for the roofs at Corinth and Isthmia, probably intending to stockpile the extras for repairs. The builders might have accidentally damaged more regular tiles during installation than anticipated, forcing them to use eaves tiles in order to finish the roofs. Alternatively, the regular tile stockpile might have been depleted gradually as tiles were damaged and replaced over the lifetimes of the temples.

9.H.2) The completed roof of the Old Temple

The final appearance of the roof could not have been perfectly regular. Weathering lines on many tiles reveal that the actual overlap dimensions varied. For example, although the full transverse dimension of the tiles is very consistent, the

⁷⁴⁷ In comparison, only six normally installed eaves tiles preserve this portion of the cover: FC 64, FC 81, FT 201, FT 209, FT 211, FT 236. However, it is uncertain how many of the type were inventoried by Robinson: see above, note 189.

transverse overlap at the back of the tile varies by 4.9 cm.⁷⁴⁸ The lateral overlap varies by 5.5 cm.⁷⁴⁹ Although changes in the transverse overlap would not have been noticeable from the ground, the shifts in the lateral overlap are more significant. Because the cover length was molded to a consistent dimension, the lateral shifts would have altered only the exposed length of the pans. At about 31 cm average, the pan length would have varied by at least 18% of its total, enough to be immediately noticeable. Moreover, several notch cuttings reveal substantial longitudinal offsets in the vertical row.⁷⁵⁰ As a result, some cover tiles might have jogged to the left or right by one or two centimeters relative to the tile above (compare to, above, Figure 1.1; Figure 3.7). Finally, in the vertical rows where a regular tile had been replaced by a re-cut eaves tile, the peaked cover of the eaves tile would have interrupted the series of convex regular covers.

Standing on the prominence of Temple Hill, however, the Old Temple must have been the highest structure in the area. Most visitors would have seen only the front edges of the eaves tiles. They could have seen the upper rows of tiles only at a distance from which centimeter-scale variations would have gone unnoticed.

⁷⁴⁸ From 17 regular and free cover tiles at Corinth. The extremes are FC 62 (7.5 cm) and FP 288 (12.4 cm). The range is slightly greater at Isthmia. Also see above, note 736.

⁷⁴⁹ From 26 tiles at Corinth. The extremes are FP 315 (8.8 cm) and FP 103 (14.3 cm). As in the previous note, the range is greater at Isthmia. Also see above, note 738.

⁷⁵⁰ e.g., the notch of FP 157 is narrower than normal. The tile above must have been shifted to the left by about 2.0-2.5 cm. Greater offsets are found at Isthmia.

CHAPTER 10: ORIGINS AND SIGNIFICANCE OF THE PROTOCOLINTHIAN ROOFING SYSTEM

This thesis has analyzed the forming, finishing, and installation of the Protocorinthian roofing system. The consequences for the understanding of Greek architecture are broad. The roofs reveal aspects of the planning, design units, and construction of the early Archaic temples at Corinth and Isthmia. The tiles also preserve an early form of band anathyrosis before its development in masonry. The manufacturing process is critical to understanding the origins of the Protocorinthian roofing system and its relationship to other regional tile systems developed in the seventh century B.C.

10.A) Significance of Protocorinthian tiles to Greek architecture

10.A.1) *Modularity and Protocorinthian roofs*

Because of the hipped design, the dimensions of the roof are governed by a consistent module.⁷⁵¹ The 45° hip line forced Greek builders to install the tiles in an orthogonal grid fixed at even multiples of the spacing units, a module of about 56 cm. As a result, the foundations of the temples at Corinth and Isthmia must have been calculated in advance in order to install tiles at the correct spacing.⁷⁵²

The margin for error would have been relatively low. The installation of the eaves tiles was the most demanding. Their lateral overlap does not appear to have been significantly altered by chiseling, probably because large alterations would have created a noticeable jog at the peaked junction of adjacent pans (see above, Figure

⁷⁵¹ Also see Rhodes 1984, pp. 74-91.

⁷⁵² For the relationship of blocks to the spacing of tiles at Isthmia, see Rhodes 1984, pp. 70-82. Individual cuttings on the cornice blocks from Corinth exhibit more variability: Rhodes 1984, pp. 98-101; Rhodes 2003, pp. 91-92. Similar observations have been made about regular block units and modularity in tiles: Liebhart 1988, p. 153; Cooper 1989, p. 41; Gebhard 2001, pp. 47, 51-53, 59. Modular archaic tile designs at Didyma and Ephesos: Schneider 1990, pp. 214-218; 1991, pp. 203-206; 1995; 1996, pp. 27-38; Schädler and Schneider 2004, pp. 27-29.

3.7). In most cases, the total length across the front of the eaves tile appears to have been shortened by less than one centimeter. With 20 to 24 tiles, this would permit less than 20 cm of adjustment over the front of the building. Because an even number of tiles was necessary at the fronts, any alternation in the number of tiles across the front would have changed the façade width by about 112 cm (two tiles, each 56 cm wide)—that is, substantially higher than the maximum adjustment permitted by the tiles.

The builders must have laid out the width of the building by multiplying the number of tiles by the spacing unit. They should also have adjusted the total by adding the length of the free cover at the center of the course and subtracting the overhangs at both sides of the walls. Although the flanks of the building were long enough that the eaves tiles might be retooled to fit any overall length, this dimension too was almost certainly calculated before construction commenced.⁷⁵³ As reconstructed by Rhodes, the cornice blocks supported timbers aligned to the eaves tiles, and groups of primary and secondary blocks repeated for every bank of five tiles (above, Figure 3.2).⁷⁵⁴ The half-timbering system, too, may have been aligned to these spacing units.

10.A.2) Architects and a unity of design

Despite the apparent complexity of Protocorinthian tiles, their design is relatively simple. The template system was suitable for mass producing units of a consistent profile that would also be able to interlock on the roof. The designers began with a pair of curved profiles for the bottom and top of a regular combination tile. Using these profiles as templates fixed at approximately the same overall length and width, they generated tiles that could interlock in a square grid. The eaves, hip,

⁷⁵³ At least an approximate length would have been surveyed: Rhodes 2003, p. 92. That the length of a temple was of importance to designers is shown, for example, by references to temples as *hekatompeda*. Also see Gebhard 2001, pp. 59-60.

⁷⁵⁴ See above, notes 92, 207, 208; and Rhodes 1984, pp. 135-136.

ridge, and free cover tiles were adapted logically from the same regular cover-pan profile to meet the special requirements at their positions on the roof. The apparent complexity of the geometry of each special type can be entirely reduced to direct, functional modifications of the regular tile-molding system. The apparatus for shaping hip tiles had only two significant modifications to the regular system: the doubled template frames and the raised back templates to simulate the slope of the roof. The ridge tiles are likewise adapted to their function of bridging the opposed hips on the flanks of the building. Only the profile of the eaves tile has been altered from that of the regular tile, but the modification was functional.⁷⁵⁵ The lower edge of the pan was flattened in order to fit over a horizontal fascia board, and the cover was peaked in parallel to the peak of the pans below. (above, Figure 3.11).

The hipped roof is consistent with this simplicity of conception. The designers abandoned the apsidal roofing systems found in some early building models of the period in favor of a roof that was identically articulated on all four sides.⁷⁵⁶ The hips eliminated the need for developing a special form of *sima* tile at the ends of the gables. The designers repeated the regular tile profiles on all four hips.

Although geometrically complex, the finished roof was austere. Perhaps the only purely decorative feature at the Old Temple was the presence of black tiles among the yellow. The Isthmia roof was monochrome, and even the additional wedge at the center of the pan at the eaves may have served the function of improving drainage (above, Figure 3.12).⁷⁵⁷

⁷⁵⁵ See above, p. 61f.

⁷⁵⁶ While building models provide too little evidence to generalize about the appearance of eighth- and seventh-century roofs, those from Perachora, the Argive Heraion, and Aetos have steep roofs terminating at a pediment-like space above a shallow front porch: Schattner 1990, pp. 22-26, cat. 1; pp. 28-31, cat. 4; pp. 33-39, cat. 6-9; pp. 182, 189. Also see Heiden 1987, pp. 23-26; Winter 1993, p. 18.

⁷⁵⁷ See above, note 101.

With such unity of design, it is likely that an architect presided over the whole construction project. Besides coordinating teams of masons, woodworkers, tile makers, and transporters, this individual would have determined the building module, designed the tile profile templates, derived the specialized tiles, calculated the number of tiles needed for the whole job, and carefully surveyed the foundations of the building to match the roof grid.

10.A.3) *Advances in building technology*

The Protocorinthian tile system ushered in a new era of monumentality in Greek architecture. With the first interlocking tile roof yet identified, the Old Temple takes a large step toward petrification. By replacing a thatched or a flat clay roof with ceramic tiles, the builders made the temple fireproof and durable.⁷⁵⁸ Not only was the roof sheathed in a permanent material, but also the walls were fortified in order to support the heavy tiles.

The restructuring of the walls at the temples of Corinth and Isthmia was radical. The builders laid courses of dressed masonry at the base and the cornice of the wall. A half-timbering system united the masonry from the base of the wall up to the rafters (above, Figure 3.2).⁷⁵⁹ Although Corinthians had already learned to work large blocks of poros limestone during the Geometric period, coursed masonry first appears in the Corinthia in the walls of the Old Temple.⁷⁶⁰ Contrary to the Vitruvian model of petrification from an existing Doric canon of wood into stone,⁷⁶¹ the transition to stone

⁷⁵⁸ See above, note 4.

⁷⁵⁹ As above, note 754; Gebhard 2001, p. 46; Rhodes 1987a, p. 478.

⁷⁶⁰ Originating in the ninth century B.C., sarcophagi cut from large poros blocks became increasingly common in Corinthian burials during the eighth century: Brookes 1981; Dickey 1992, pp. 25-27; Gebhard 2001, pp. 50-53; Pfaff 2007, pp. 472-473, 503-505, 526, 530-531; Rhodes 1987b. Also see Rhodes 1987a, p. 478.

⁷⁶¹ Vitr. 4.2.1-6 was the basis for this interpretation: e.g., Dinsmoor 1950, pp. 50-53. Many authors have since raised criticisms of the model: e.g., Kienast 2002; Klein 1998, pp. 340-345; Rhodes 1984, pp. 142-145, 156 note 45; 1987a.

at the temples at Corinth and Isthmia was for structure. The masonry was concealed beneath the timber framework and stucco panels of the finished buildings.⁷⁶² Both temples appear to have been over-structured, with more reinforcement than actually was needed for the roof.⁷⁶³

The use of a standard module for the tiles anticipated the development of regular ashlar masonry in the following generations. The blocks of the Corinth and Isthmia temples did not have a consistent course height, and the lengths vary significantly.⁷⁶⁴ The widths also appear to have varied, perhaps narrowing from socle to cornice and varying by a few centimeters on each of the four cella walls. The tiles, which were created in a fixed template, were standardized before the masonry. The roof tiles also made way for the introduction of moldings. Although the tiles were struck from malleable clay in an open form, both the tiles and stone moldings are trimmed by reference to standard templates.

10.A.4) Protocorinthian tiles and anathyrosis

The first Protocorinthian tiles appear to have led to the standardization of anathyrosis in Greek masonry. In the standard “band anathyrosis,” only the upper edges and sides of the joint faces of blocks are smoothed, while the roughly worked interior is recessed.⁷⁶⁵ By greatly reducing the contact area, the masons save a considerable amount of time while preparing the joints without creating any gaps in the outer faces of the wall. Band anathyrosis on stone, however, appears only by the beginning of the sixth century B.C. at monuments such as the Temple of Artemis at

⁷⁶² Rhodes 1987a, p. 478; 2003, p. 91.

⁷⁶³ Rhodes 1984, p. 146; 1987a, p. 478.

⁷⁶⁴ Broneer 1971, p. 15; Gebhard 2001, p. 47; Rhodes 1984, p. 18.

⁷⁶⁵ Coulton 1977, p. 46; Ginouvès and Martin 1985, p. 105 (“anathyrose en pi”); Martin 1965, pp. 194-199; Orlandos 1968, pp. 99-100.

Corfu.⁷⁶⁶ Greeks appears to have pioneered this technique, which was not used in the Near East and does not appear on monuments in Lydia until the sixth century.⁷⁶⁷

The seventh-century antecedent, already present at Corinth and Isthmia, is “hollowed anathyrosis.”⁷⁶⁸ In this early form, anathyrosis was created by carving concave joint faces, leaving only the outer edges of the joints in contact. Although perhaps slightly easier to carve at first, edge anathyrosis limited the reworking of blocks after they had been laid in position. The faces of the blocks were dressed back to an even plane after the wall was laid. If any blocks were set out of alignment, masons would have been unable to adjust the margins of the blocks without exposing gaps in the joint seams. Hollowed anathyrosis appears on the joint faces and the bottom of the blocks from Corinth and Isthmia.⁷⁶⁹

Anathyrosis also is found on the horizontal joint faces of the first Protocorinthian tiles. The technique is closer to band anathyrosis. The cover rabbets have a raised lip running on the outer edge which would contact the tile below on the roof (above, Figure 9.24). By carving out excess clay from behind the lip, the tile makers substantially reduced the contact zone which the builders would inevitably chisel to fit the tile in position.⁷⁷⁰ The feature was clearly no accident. The lip is

⁷⁶⁶ Coulton 1977, p. 46; Schleif, Rhomaios, and Klaffenbach 1940, pp. 21-47.

⁷⁶⁷ In Lydia, the treatment of the joint faces often resembles band anathyrosis but is less systematic. Such banded joints appear on the internal crepis wall in Karnıyarık tepe and the Lydian fortifications of Sardis, both dated in the first half of the sixth century B.C.: Ratté 1989, pp. 48-50, 86; 1994a, pp. 160-161. Ratté suggests that Lydian and Greek masonry techniques developed under mutual influence: Ratté 1989, pp. 97-102; 1993.

⁷⁶⁸ After Ginouvès and Martin 1985, p. 105 (“contact par les arêtes”). For general descriptions of the technique, also referred to as “edge” anathyrosis, see: Coulton 1977, p. 47; Martin 1965, pp. 195-196; Orlandos 1968, p. 99.

⁷⁶⁹ Rhodes 1984, pp. 18-20, 133; 1987a, p. 478. The same technique may be observed at the Argive Heraion: Wright 1982, p. 191. The *in situ* stylobate blocks belonging to the seventh-century Archaic Temple to Hera have oblique, concave joint faces. Because the joint faces are hollowed, wide gaps have opened at breaks on the faces of the blocks. For a summary of proposed dates for the temple, see Billot 1997, pp. 23-26, 70. Hollowed anathyrosis occurs in the sixth century at the Heraion of Olympia, the Artemis Temple at Corfu (where some blocks have band anathyrosis), and the West Building at the Argive Heraion: Amandry 1952, pp. 242-243 (Argive Heraion); Martin 1965, p. 196 note 1; Schleif, Rhomaios, and Klaffenbach 1940, p. 21 (Corfu).

⁷⁷⁰ See above, p. 303f; Figure 3.10, Figure 9.24.

present on every cover rabbet of the Old Temple tiles which was not deeply chiseled. Although the pan rabbet was cut into the tiles at Corinth only during installation, a raised lip was left on the outer edge of the pan rabbet at Isthmia, which was cut before firing.

Despite the lip, the interior of the rabbets still had to be chiseled in many cases at Corinth and Isthmia since the rim was too low. The designers appear to have addressed this specific problem at Delphi by molding thicker tiles. They cut deep rabbets, leaving behind a high rim and consequently reducing the likelihood that any material behind the rim would have needed to be removed (above, Figure 3.10).

A similar approach was taken for the eaves tiles. Already noted in the discussion of framed edges in the previous chapter, the free side of the pan was not cut back from the vertical frame (above, Figure 3.11; Figure 9.4).⁷⁷¹ As a result, the pans of eaves tiles were slightly longer than regular pans and could be trimmed slightly when the tiles were installed.⁷⁷² Toward the back of the tile, however, the free edge of the pan was often trimmed to an oblique angle to resemble the regular tiles. When installed, only the front edge of the tile would have been visible from the ground. By shortening the pan at the back where it was overlapped by the adjacent cover, the tile makers reduced the adjustments required for installation without changing the outside appearance of the roof. This type of anathyrosis is standard in the developed Archaic Corinthian roof system, in which the eaves pans are lengthened by two or three centimeters at the front edge.⁷⁷³

Therefore, band anathyrosis was first standardized on tiles, not masonry. The hollowed anathyrosis on the blocks was expedient but unsuited to creating a uniformly

⁷⁷¹ See above, p. 270.

⁷⁷² See above, 717. The pans of eaves tiles have been lengthened by about three centimeters relative to the others. Most of the extension was needed to create a continuous front face with the adjacent pan.

⁷⁷³ The roof of the mid-sixth-century Temple to Apollo at Corinth had such eaves tiles: Winter 1993, p. 28, pls. 8-9.

dressed surface. Not only were the interstices of the masonry filled with clay,⁷⁷⁴ but also the upper part of the wall at Corinth was probably mud brick (above, Figure 3.2).⁷⁷⁵ The irregular surfaces of the wall were concealed by plaster and timber. The tiles, on the other hand, required a tighter fit at their external joints. Seams at the lateral joints would be noticeable because they were opposite from the seamless cover-pan joints of the combination tiles. More important than appearance, however, the joints needed to be waterproof. The patches of mortar preserved on the tiles probably worked as a sealant,⁷⁷⁶ but most of the work went first into chiseling an exact fit.

The horizontal band anathyrosis saved labor. Besides time, the risk of accidentally damaging the tile while chiseling its thinnest and most vulnerable areas would have been reduced. After tailoring more than 1,500 tiles to fit in place on the roof of the Old Temple, the builders would have recognized that the raised lip at the edge of the covers saved them many hours of carving. For the next job at Isthmia, they may have instructed the tile makers to add the anathyrosis to the pan rabbets, and the rims were further amplified at Delphi. The same masons who had erected the walls may also have chiseled and installed the tiles. Before the end of the seventh century B.C., these masons would have had many opportunities to transfer band anathyrosis from the horizontal joints of tiles to the vertical joints of blocks

10.A.5) Creating and maintaining the Protocorinthian tile system

The implementation of the Protocorinthian roofing system was inefficient despite its simple design. The double curvature of the pans and covers created difficulties in aligning and interlocking individual tiles, since minor distortions inevitably introduced during the fabrication and firing of tiles resulted in the

⁷⁷⁴ Rhodes 1984, p. 19.

⁷⁷⁵ Roebuck 1955, p. 157; Rhodes 1984, p. 102; Rhodes 2003, p. 88.

⁷⁷⁶ See above, notes 312, 730.

substantial misalignments that needed to be retooled during installation. The secondary hand-cutting of notches, bevels, and rabbets introduced variations that exacerbated the mismatches. The joints had to be chiseled back after firing for their final installation on the roof in order to achieve the tight seal necessary for protecting the woodwork from rainwater. The forming and trimming of combination tiles was so inefficient that they were dropped as a standard for any regional tile system before the end of the Archaic period.⁷⁷⁷ Thus, the Protocorinthian roofing system was appropriate for an early monumental temple, but its tiles were poorly suited to mass production.

Potters must have been recruited to shape the tiles found at Corinth, Isthmia, Perachora, and Delphi, but these isolated projects were insufficient to maintain full-time work. As demonstrated in Chapter 8, both the Corinth and Isthmia roofs could have been produced in a single potting season by a small team of fewer than seven workers, one donkey, and an ox cart. The other known Protocorinthian roofs include the tile from the Sanctuary of Demeter and Kore at Corinth, the tiles from Perachora, and at least two roofs at Delphi.⁷⁷⁸ These six to eight Protocorinthian roofs would have required less than a decade of summertime work to produce. The Archaic Corinthian system was not introduced until 620 to 600 B.C. according to Winter.⁷⁷⁹ If this had been the reality, a team of specialist tile makers would have been occupied making Protocorinthian roof tiles for only one of the four or more decades between the introductions of the Protocorinthian and developed Corinthian systems.⁷⁸⁰

⁷⁷⁷ Combination tiles are a regular feature of several early roofing systems, but regular Corinthian tiles are usually made as separate pans and covers after ca. 540 B.C.: Winter 1993, p. 82.

⁷⁷⁸ See above, notes 104-105, 109, 111.

⁷⁷⁹ Winter 1993, p. 20. Four antefixes from Corinth, Tiryns, the Athenian Acropolis, and Eleusis are the only examples dated to this early period because their decoration resembles that of roofs in North-Western Greece and Laconia: Winter 1993, pp. 63-65 (Antefix Type Ia).

⁷⁸⁰ Also see Winter 2000, p. 256.

The tile workers are unlikely to have exported tiles from a permanent worksite established in Corinth to the other sites where Protocorinthian tiles have been found.⁷⁸¹ As demonstrated by the cost analysis, the final transportation costs were high even over short distances,⁷⁸² providing a strong incentive for the tile makers to relocate temporarily near each commission. This itinerant model is typical of potters who produce the large, relatively expensive *pitharia*.⁷⁸³ Such potters typically work within one region, traveling an established circuit rather than wandering aimlessly in search of commissions. However, too few Protocorinthian roofs were ever created to establish a circuit. Although the Corinth and Isthmia temples may have been constructed by the same team of workers, it is unlikely that the whole team could have stayed intact and maintained a continuous tradition through the end of the seventh century B.C. Either the Corinthians lost the knowledge of tile making and re-imported it for the sixth-century Corinthian tile system, or else they preserved the techniques by another means than a continuously operating workshop.

As already demonstrated, the manufacturing techniques for the tiles were relatively simple. A single itinerant specialist who knew the general principles of shaping Protocorinthian tiles could have kept the tradition alive.⁷⁸⁴ For each project, this individual could have recruited the small teams of potters required to execute the job, provided templates, and guided the team through the process of shaping the tiles. Although the specialist may not have been intimately acquainted with the performance characteristics of local clays at every site with Protocorinthian tiles, he could have left the problems of extracting raw materials, mixing paste, and firing tiles to the potters with experience in the area. The potters would have taken off a season from pot

⁷⁸¹ Also see Williams 1988.

⁷⁸² See above, p. 258 and Table 8.4.

⁷⁸³ See above, pp. 175, 217; notes 250, 588.

⁷⁸⁴ The work of several itinerant tile workers has been identified later in the Archaic period, e.g.: Mertens-Horn 1990; Skoog 1998, pp. 109-113.

making for the roofing project, but they could have returned to their normal work after completing the job. Although this model is conjectural, it explains how a tradition of tile making could have been maintained in spite of only sporadic commissions.

The specialist would have had expertise in a craft other than tile making. Considering the range of tasks involved in building the Old Temple, this individual may have been an architect and builder knowledgeable in woodworking and stonecutting. The craftsman may instead have been a sculptor familiar with carving and bronze working. Coroplasts are often associated with bronze workers.⁷⁸⁵ For example, craftsmen produced tile roofs with sculpted decoration alongside bronzes at the Workshop in Poggio Civitate.⁷⁸⁶ Coroplasts apparently had become full-time specialists when the Greek Tile Works at Corinth started production.⁷⁸⁷ An itinerant Corinthian sculptor active during the seventh-century may have created the Protocorinthian tile system. This pioneer of tile making is reminiscent of the legendary Butades, a sculptor from Sikyon whom Pliny credits with the invention of human-head antefixes.⁷⁸⁸

10.B) Origins of the Protocorinthian tile system

The sophistication of the roof of the Old Temple contradicts the expectation that any technology begins with a simple prototype and gradually acquires complexity through several generations of production. Some scholars have objected to the idea

⁷⁸⁵ Such connections are commonly made: Aversa 2002, pp. 232, 238, 242, 253, 261; Merker 2006, pp. 20, 81; Muller 2000, pp. 93, 97; Nielsen 1998, pp. 103-104. Bronze workers have experience sculpting clay models to prepare casts. Connections between bronze workers, sculptors, coroplasts, and architects have often developed. The most prominent examples are the famous artists of the Italian Renaissance since Giotto, who were broadly skilled in the arts and accepted a wide variety of commissions: see, e.g., Calkins 1979, pp. 267-270.

⁷⁸⁶ See above, notes 274, 590.

⁷⁸⁷ See above, p. 213, note 554.

⁷⁸⁸ Plin. *HN* 35.151-152. Butades has been connected with the decoration of the North-Western Greek System; for discussion and references, see: Winter 1993, pp. 17, 111-112, and 17 n. 2, 111 n. 4. Also see below, note 876, and the discussion of Demaratus.

that such complex objects as the tiles from the Old Temple at Corinth could have been a sudden invention. Ernst-Ludwig Schwandner proposed an evolutionary sequence from simple curved Laconian-type tiles that gradually acquired the characteristics of the Protocorinthian tile system.⁷⁸⁹ However, Örjan Wikander argued against Schwandner's hypothesis and suggested instead that the tiles could have been invented directly in their complex form by copying non-ceramic prototypes.⁷⁹⁰ The technical evidence presented in the previous chapters casts light on this problem of origins.

The basic set of techniques used to make the tiles must have been well known to potters. The simple and efficient molding system for the tiles may be compared to the wood frames used to mass produce mud bricks since the beginning of cities in the Near East,⁷⁹¹ and mud bricks probably were used for the upper parts of the walls of the Old Temple itself. The adaptation of brick frames to strike the upper surfaces of Protocorinthian tiles certainly would have been within the creative capacity of Corinthian potters. Only a few logical modifications to the templates were required to produce the specialized tiles, and the designers could have worked out the correct configuration of the frames with a few test units at the beginning of the job. The need for notches and bevels would have become clear after preliminary tests of the interlocking system. The frequent chiseling to correct misalignments argues against the Corinthians' having much experience building other monumental roofs. In all, the simplicity of its conception and the inefficiency of its implementation suggest that the Protocorinthian roofing system could have been invented specifically for the Old Temple.

⁷⁸⁹ Schwandner 1990.

⁷⁹⁰ Ö. Wikander 1990, pp. 288-289; 1992, pp. 153-156. Wikander is supported by Winter 1993, p. 12, note 3.

⁷⁹¹ Molded bricks are documented as early as the eighth millennium B.C. in Anatolia: Aurenche 1993, p. 84. Also see Gebhard 2001, p. 59.

Still, it is difficult to support Wikander's scenario of an invention entirely without precedents in fired clay. The basic element of the design for the whole roof begins with the curved profiles of the cover and pan. The curvature of the tiles may have been developed to funnel water down the roof efficiently.⁷⁹² However, the cover articulated as a separate entity raised above the pan is a feature unique to assembled tiled roofs.⁷⁹³ Although he disagrees with Schwandner's hypothetical antecedents to the combination tile, Wikander is forced to propose an even less plausible origin for the Protocorinthian roof—wooden shingles.⁷⁹⁴ Unfortunately, Wikander does not present any evidence that Late Geometric buildings had shingled roofs, and he does not illustrate a shingling system that is profiled like the Protocorinthian roof tiles.⁷⁹⁵ Rather than an illusory wooden antecedent, the Protocorinthian tile system closely resembles other seventh-century roofs with separate covers and pans. The Corinthians, of course, were free to design any sort of curved profile over the full length of their combination tiles. They might have designed a continuous arc without differentiating the cover and pan elements. Instead, they produced a system which ostensibly differs little from another Peloponnesian roofing system which will be discussed later (below, Figure 10.2).⁷⁹⁶

The form of the tiles contradicts Wikander's proposal. Nevertheless, in light of the technical analysis, Schwandner's multi-stage sequence of hypothetical roofs evolving into the Old Temple system remains unsupported. A middle ground is more plausible. Corinthians must have gone to the trouble of articulating covers and pans in

⁷⁹² Schwandner 1990, p. 292. I thank Charles K. Williams, II, Fred Cooper, and Robin Rhodes for bringing this explanation to my attention.

⁷⁹³ Rhodes 1984, p. 107; Schwandner 1990, pp. 295-296; Rhodes 2003, pp. 87-88. Cooper discusses the issue: Cooper 1989, pp. 30-32.

⁷⁹⁴ Ö. Wikander 1990, p. 289; 1992, p. 156. This explanation is not accepted by Skoog 1998, p. 26.

⁷⁹⁵ Although Wikander does not refer to it, Benndorf argued in a lengthy article that tile roofs were derived from wooden prototypes. He compared terracotta tiles to Anatolian tomb reliefs and wooden roofs in European vernacular architecture: Benndorf 1899, pp. 21-37.

⁷⁹⁶ Winter 1993, pp. 149-152, 153-157.

their combination tiles because they were imitating of some preexisting roof with separate, functional cover and pan tiles—at least one earlier tile roof.⁷⁹⁷

Although Protocorinthian tiles must have followed a predecessor, there is no reason to postulate a precursor to the Old Temple in Corinth. Considering the inefficiencies of the Protocorinthian system, it is equally possible the Corinthians were no more than distantly acquainted with its predecessor.⁷⁹⁸ The tiled roof may have been introduced into Mediterranean Iron Age architecture at any center which had contacts with Corinth by the early 7th century B.C. Corinthians could have synthesized the full Protocorinthian system by imitating tiles from a standing building.

10.C) Possible antecedents to the Protocorinthian tile system

Because the Protocorinthian roofing system is traditionally dated earlier than all other Archaic tiles, the systems which have been assumed to develop afterwards must be reexamined carefully in search of the hypothesized predecessor. Winter's regional classification serves as a useful basis for reviewing the alternatives in the Greek world. Furthermore, in a 1992 article, Wikander tracks the emergence of all tiles in the central Mediterranean over the course of the seventh century.⁷⁹⁹ In the third quarter of the seventh century B.C., the generation immediately following the development of the Protocorinthian tile system, he counts only the early roofs from Olympia, Thermon, San Giovenale, Acquarossa, and Poggio Civitate.⁸⁰⁰ Other early

⁷⁹⁷ This "prototype" theory has appeared in other forms though without much supporting evidence. Billot proposes a predecessor in the form of Winter's Argive system: Billot 1990, pp. 121-122; Badie and Billot 2003, pp. 283-289. Cooper favors a similar "prototype roof" before the Protocorinthian system, an idea that she attributes to J. J. Coulton: Cooper 1989, pp. 19-20, 29-32. Also see Rhodes 2003, p. 88. For a discussion of the Protocorinthian in relation to the Laconian system, see Skoog 1998, pp. 21-26.

⁷⁹⁸ This possibility was mentioned by Cooper 1989, pp. 31-32.

⁷⁹⁹ Ö. Wikander 1990; 1992; Winter 1993.

⁸⁰⁰ Ö. Wikander 1992, pp. 157-158.

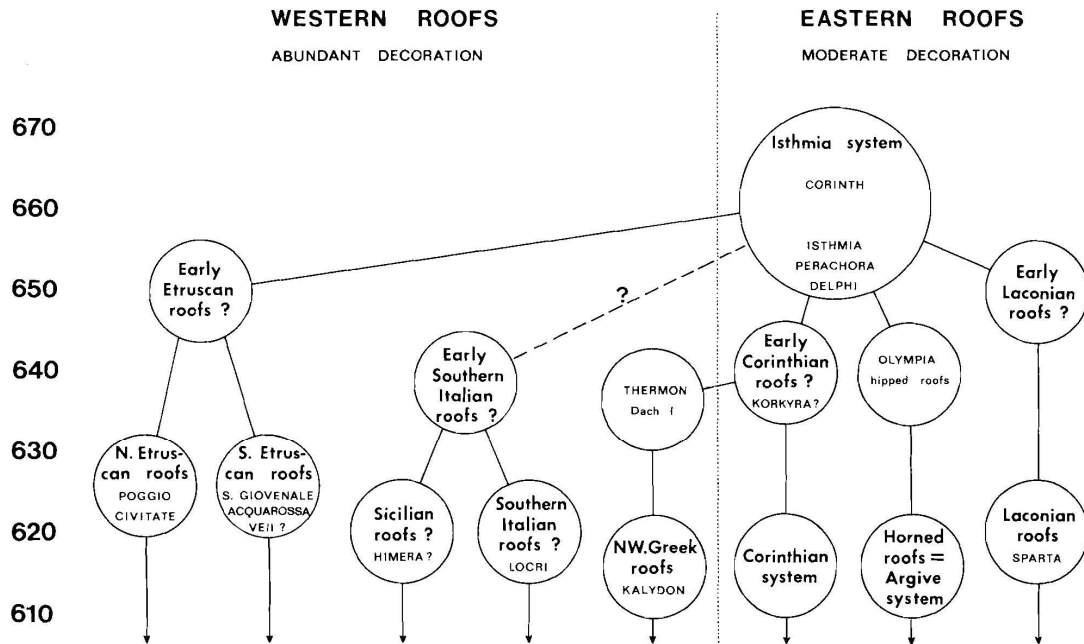


Figure 10.1 Wikander's hypothetical "stemma" of seventh-century roof systems (Ö. Wikander 1992, p. 160 fig. 5)

possibilities are from Sparta and Veii, but the dates are less certain.⁸⁰¹ Wikander surmises that Northwest Greece, Central Italy, and perhaps Laconia adopted roofs during the generation after the Corinthian invention, whereas South Italy, Sicily, and Ionia were slower to experiment with terracotta tiles. Continuing the survey through the last quarter of the century, Wikander proposes a complex model with linear evolution for every regional tile system, each originally sprouting from Protocorinthian roofs (Figure 10.1).⁸⁰²

⁸⁰¹ Wikander also mentions the first roofs from Kalydon, Locri Epizefyrii, and Himera, although the date of each has been subsequently lowered to the final quarter of the seventh century or later: Ö. Wikander 1992, p. 158 notes 62, 63, and 64. Winter initially proposed a high date for the Daedalic antefixes at Kalydon, which she has since revised to 600-590 BC: Winter 1978, p. 30; 1993, pp. 119-121, especially note 35. The first roof at Locri is generally placed in the final quarter of the seventh century despite the initial proposal by the excavator, which is supported by no context evidence: de Franciscis 1979, p. 70; C. Wikander 1990, p. 281 note 26. The high date for the unusual lateral simas from Temple A at Himera is based not on closed contexts associated with the building or tiles but rather the earliest votive material recovered from the area: Adriani 1970, p. 86; C. Wikander 1986, pp. 12, 36-37 (no. 19); C. Wikander 1990, pp. 278-280; Winter 1993, p. 275 note 3.

⁸⁰² Ö. Wikander 1990; 1992, pp. 159-161.

10.C.1) *Early tiles of the Greek Mainland*

Within Winter's regional typology of Greek architectural terracottas, it is possible immediately to eliminate the North-Western Greek and Laconian systems as likely antecedents for Protocorinthian roofs. The North-Western Greek roofs are limited to sanctuaries at Corfu, Kalydon, Thermon, and the nearby Taxiarchus.⁸⁰³ The earliest roof from Thermon is dated ca. 630-620 B.C. by the sculptural style of molded heads at the eaves.⁸⁰⁴ With their exuberant, brightly painted plastic decoration, these early roofs are unlikely to have provided the inspiration to the comparatively austere Protocorinthian tiles.

The Laconian system may have emerged early in the seventh century B.C.⁸⁰⁵ Felsch has argued for an early introduction of Laconian tiles in Central Greece. He dates three Laconian pan tiles to the first half of the seventh century B.C. by the style of the dancing warriors stamped on their undersides.⁸⁰⁶ Two came from Tanagra, and the provenience is unknown for the piece in the Kanellopoulos Museum. However, Felsch does not supply convincing evidence that such pan tiles were not created later using stylistically outmoded stamps.⁸⁰⁷

Winter assigns a date of 650-620 B.C. for the first Laconian roof at the Sanctuary of Artemis Orthia.⁸⁰⁸ The roof, however, is poorly preserved. Besides three

⁸⁰³ Winter 1993, pp. 110-133. Also see Aversa 2002, pp. 234-238. Later Archaic roof tiles from Epidamnos and Stratos are related to this tradition: Croissant 1988, p. 136; Eggebrecht 1988, pp. 240-241; Zeqo 1986 (Epidamnos); Schwandner 1996 (Stratos).

⁸⁰⁴ Winter 1993, pp. 112-115. Gerhild Hübner is publishing the roofs from Thermon, whose dates will not be raised (pers. comm. 2005).

⁸⁰⁵ Felsch 1979; 1990; Skoog 1998; Winter 1993, pp. 95-109.

⁸⁰⁶ Felsch 1979, pp. 4-7, 25, figs. 1, 2, pls. 1.1-3; 1990, p. 312-313.

⁸⁰⁷ Felsch points to a stamped fragment recovered from a context dated to the second quarter of the seventh century B.C. in Eretria: Felsch 1990, pp. 314-315. The object had been cut into a small disc, probably to serve as the lid of a storage jar. From Felsch's description, it is perfectly flat on the stamped side and, therefore, no Laconian tile. Others have rejected Felsch's high date: Skoog 1998, pp. 125-126; Ö. Wikander 1992, p. 155, note 33; Winter 1993, p. 93 note 4.

⁸⁰⁸ Dawkins 1929, pp. 117-144; Winter 1993, pp. 95, 98-102, 106-108. Winter follows the revised pottery chronology for the sanctuary: Boardman 1963. Also see Skoog 1998, pp. 45-51. I thank James Whitley and the British School at Athens for permission to examine the architectural terracottas excavated from the sanctuary of Artemis Orthia.

antefixes with incised decoration and fragments of plain tiles, Winter assigns to the early roof the single fragments of a disk acroterion, a sima, and what may be a geison tile.⁸⁰⁹ Of these fragments, the excavators found eleven covers and pans, the acroterion, and the geison in contexts associated with Laconian I and Geometric pottery.⁸¹⁰ However, the central portion of an antefix and an acroterion fragment decorated with gadroons were recovered from strata with similar pottery.⁸¹¹ Winter dates these latter fragments in the final quarter of the seventh century B.C. and suggests that they belonged to a replacement roof of the temple.⁸¹² Because the four tiles that the excavators associated with the earliest pottery do not form a single, coherent roofing system, the significance of the reported associations with Laconian I and Geometric pottery is doubtful. The covers and pans from these layers cannot be assigned to one roof or another.⁸¹³

Certainly the Laconian roofing system had developed by the second half of the seventh century, but the available evidence does not suggest a prototype for Corinth. In comparison to Protocorinthian tiles, the first preserved Laconian tiles are even more fastidiously shaped and decorated. There are no combination tiles in the system, but the acroteria, covers, and pans are carefully formed with almost perfectly circular sections. Every tile is coated in black paint which preserves a gloss on many examples. Emphasizing the circular profiles of the cover tiles, a compassed radial pattern accented with red and white paint decorates the earliest series of antefixes. Unlike the complicated system of interlocking in Protocorinthian tiles, the Laconian

⁸⁰⁹ Winter 1993, pp. 98-100.

⁸¹⁰ Dawkins 1929, pp. 130, 137 (no. 15); 141 (no. 36); 142 (plain tiles).

⁸¹¹ Dawkins 1929, pp. 136 and 119 fig. 87 (no. 11); pp. 130, 139, pl. 25 (no. 28).

⁸¹² Winter 1993, pp. 100, note 17, 103 (acroterion Type II var. 2a, 625/620-580 B.C.), 107 (antefix Type I var. 2, 620-600? B.C.), note 17.

⁸¹³ The 1906-1910 dig was an early model of stratigraphic excavation, although the recording was minimal: Boardman 1963, p. 1; Dawkins, Droop, and Wace 1930. However, some have disregarded the contexts of the third quarter of the seventh century with tiles, e.g.: Felsch 1990, pp. 312-313; Ö. Wikander 1990, p. 287; 1992, p. 156, note 50. On the sand layer: Boardman 1963; Dawkins 1929, pp. 15-16, 19-20.

covers and pans are tapered, eliminating the need for any notches, bevels, or flanges. To conclude, although a simpler, undecorated Laconian roof could have been a plausible prototype for the Old Temple roof, no credible evidence of such a roof has been identified.⁸¹⁴

Much stronger candidates for the Protocorinthian prototype roof have been excavated at Olympia. Mentioned only briefly by Wikander, two early roofs from the site have since been classified by Winter in her “Local” Argive system.⁸¹⁵ Besides the fragments from the Argolid from the Argive Heraion, Nemea, Halieis, and Mases, Winter includes examples from the Aphaia sanctuary on Aegina, Delphi, and Kombothekra (near Olympia) and a model roof from the Athenian Acropolis.⁸¹⁶ Since Winter’s publication, similar tiles may be added to the list from Troizen,⁸¹⁷ Kaulaureia on Poros,⁸¹⁸ the Artemision at Ephesos,⁸¹⁹ and even Kroton, where a single “Local” Argive cover was found on the surface.⁸²⁰ Because Winter’s terminology does not acknowledge their relatively broad distribution outside the Argolid, these roofs will instead be referred to as the “Peaked Antefix” system here, after their most diagnostic feature.

Marie-Françoise Billot has classified all but the most recently published tiles from Ephesos and Kroton in a formal typology distinguishing several forms of covers and antefixes.⁸²¹ Although most of these covers are gabled, the type which appears to be the earliest has convex covers which transform to a peak at the eaves (as below, Figure 10.2). This characteristic, shared only with the Protocorinthian roofs from

⁸¹⁴ Also see Skoog 1998, pp. 23-24.

⁸¹⁵ Heiden 1990, pp. 41-42; 1995, pp. 12-18; Winter 1993, pp. 150, 160 (Antefix Type I var. 1), 168-169 (pans, covers, and hip tiles)

⁸¹⁶ Winter 1993, pp. 149-157, 156 figs. 16-17; also see Cooper 1989, pp. 33-47.

⁸¹⁷ Badie and Billot 2003, pp. 281-295.

⁸¹⁸ Badie and Billot 2003, pp. 314-316.

⁸¹⁹ Schädler and Schneider 2004.

⁸²⁰ Aversa 2002, p. 263 and 264 fig. 23.

⁸²¹ Billot 1990, pp. 111-122, 125; Badie and Billot 2003, pp. 283-285.

Corinth and Isthmia, is present on the antefixes from Delphi and Olympia.

Consequently, Billot classifies the roofs from all four sites together.⁸²² The roof from Ephesos with convex covers should belong to the same group, but its antefixes have not been identified.⁸²³

The early group from Olympia is best represented. In his catalogue of the fragments, Joachim Heiden distinguishes two roofs of slightly different dimensions, of which “Roof 1” is the better preserved.⁸²⁴ A small quantity of covers and pans belong to Roof 1, including both regular and hip tiles, and it has three antefixes. Only the eaves pan and the ridge tile have not been identified. With its convex covers, transition to the peak at the eaves, and hip tiles, the roof is generally viewed as one of the first derived from the Protocorinthian system at Corinth and Isthmia.⁸²⁵ The gabled covers from the other sites are presumed to have belonged to the next generations of the Peaked Antefix system. The hipped roof appears later at Nemea, Kombothekra, and in the Athenian Acropolis model. Only two fragments of simas from Delphi can be associated with the roofing system.⁸²⁶ Others of the roofs may have been hipped as well.

With the exception of its reduced scale and unattached covers and pans, the Olympia roof closely resembles that of the Old Temple (Figure 10.2; compare to Figure 3.7). The low, convex curvature of the covers is similar, as is the slight concavity on top of the pans. The Olympia tiles were undecorated, finished only with

⁸²² Badie and Billot 2003, p. 283 (Type I).

⁸²³ Also see below, note 835.

⁸²⁴ Heiden 1995, pp. 12-18, 171-172, fig. 2, pls. 1-2. I thank Reinhard Senff, director of the Olympia Excavations, and the German Archaeological Institute for their permission to examine the Archaic tiles at Olympia, including those of Heiden’s first two “Corinthian” roofs.

⁸²⁵ e.g., Cooper, pp. 38-40, 42, 45-47, 62; Gebhard 2001, pp. 54-55; Heiden 1987, 1995, pp. 15-16; Ö. Wikander 1990; 1992, pp. 157-158; Winter 1993, p. 150 (“transitional roofs”). However, Billot suggests the two systems may have developed independently from Mycenaean tiles, which she believes to have survived the Dark Ages within a fully-fledged roofing system: Badie and Billot 2003, pp. 286-287. Such an argument is groundless, as demonstrated above, pp. 37-56.

⁸²⁶ Le Roy 1967, pp. 28-32 (Roof 5.1/S.102, 6.1/S.3, 6.2/S.4+S.119); Winter 1993, p. 158.

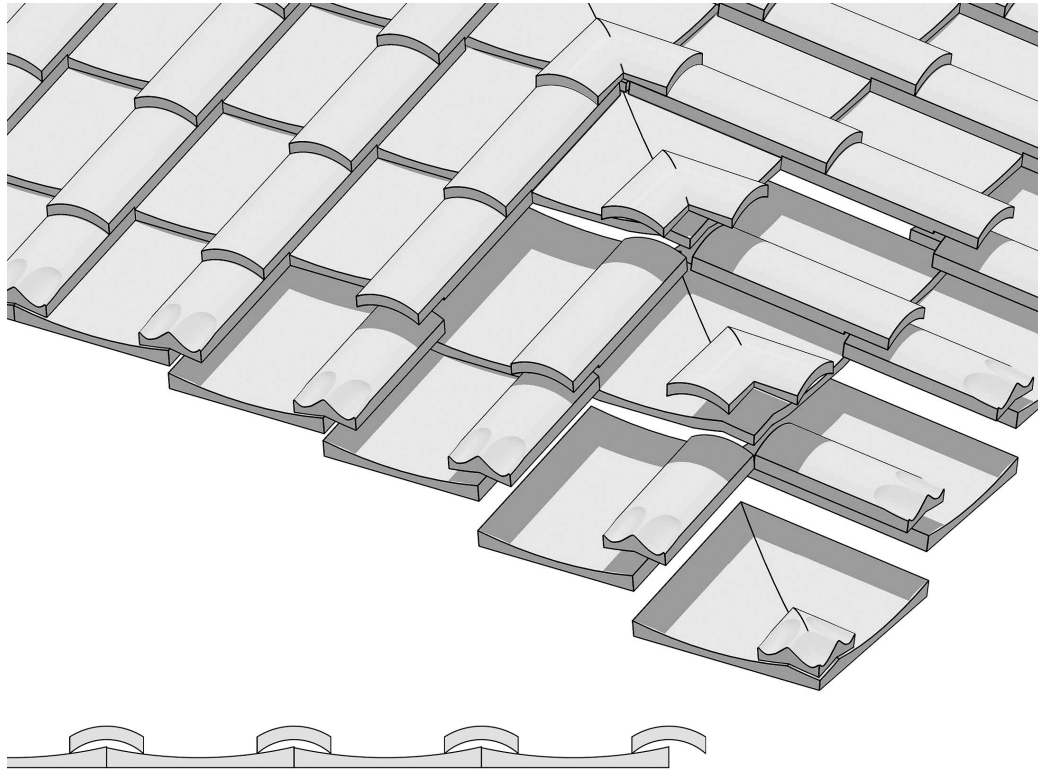


Figure 10.2 Olympia “Roof 1”: (above) corner showing overlaps; (below) regular tile profile (the eaves hip tile is restored by analogy to the regular hip tiles)

a pale buff slip to conceal the tempered fabric. Like all Protocorinthian tiles, the Olympia covers are formed on a curved base mold indicated by the presence of a dusty parting agent on the underside. The same parting agent is found on the pans, but the bottom is flat, allowing the tile to be created on any level surface using just side frames. The Olympia tiles have no pre-cut notches, bevels, or rabbets. The first two were unnecessary because the covers were shifted forward, their back edges abutting the pans (Figure 10.2). A rabbet at the front edge of the cover was cut after firing whenever needed.

At the eaves, both the Olympia and Corinth covers were peaked. The Olympia antefixes, however, were formed as regular convex covers, and the peak was simply cut out from the front edge. As a result, the front profile of the Olympia antefixes varies widely. The special template for molding the eaves tiles at Corinth would have

been unnecessary at Olympia. Because the regular pans at Olympia were flat bottomed, the same tiles could have been used at the eaves.

As at Corinth, the geometry of the Olympia hip cover is that of two regular covers attached to one another across the hip line. The hip line on the cover moves from an articulated ridge at the back to a valley at the front, as on the Protocorinthian hip cover. However, the hip covers do not appear to have been designed to fit over two opposed slopes. Instead, the tiles appear to have been molded in a flat double frame. To accommodate the slopes, the hip tiles had to be heavily chiseled after firing. The designers of the Protocorinthian tiles anticipated this problem and elevated the back templates of the hip frame to simulate the slope of the roof, thereby reducing the amount of post-firing adjustments. As expected from their analogues at Corinth, the hip pans at Olympia have a double profile that meets at a slightly recessed cusp over the diagonal hip line.

Thus, Roof 1 at Olympia is strikingly close to the Protocorinthian roofs in shape and design. The profiles of the covers and pans at both sites are similar, the hip tiles are geometrically alike, and the covers and pans at the eaves closely resemble one another. The primary forming techniques were identical. The Olympia roof, however, required less equipment and labor to produce. No base molds for the pans were required, and the antefixes were created simply by trimming a regular cover after molding. The complex set of cuttings necessary for interlocking the Protocorinthian combination tiles was eliminated at Olympia.

Furthermore, the Olympia design appears less planned than Corinth's. The design of the hip tiles at Olympia failed to anticipate the slope of the roof, requiring substantial trimming during installation, but the problem was remedied at Corinth. The use of a special template to shape the peaked Protocorinthian eaves cover should be viewed as a refinement that regularized the irregular, scooped-out antefixes at

Olympia. Most indicative of all, however, was the choice at Corinth to produce combination tiles, which cannot be explained without postulating a preceding roof with separate covers and pans. The Olympia roof, in fact, has exactly the characteristics expected of such a predecessor.

The archaeological evidence favors the identification of this Peaked Antefix system as the prototype for the roofs of the Corinthia. The three early roofs with convex rather than peaked regular covers from Olympia and Ephesos are firmly dated within seventh-century contexts. Only the antefix at Delphi has no reported findspot.⁸²⁷

Recently published by Ulrich Schädler and Peter Schneider, the early tiles from the Artemision at Ephesos were concentrated in a stratified dump 15 m east of the so-called Peripteros below the Kroisos temple.⁸²⁸ The deposit was rich in pottery of the second half of the seventh century B.C., and the layers below the primary tile dump were deposited immediately before 600 B.C.⁸²⁹ The roof is clearly a product of the seventh century and has been assigned to the Peripteros, which was the most important building in the area in its time and appears to have gone out of use at the same time as the tile deposit.⁸³⁰ The date of its construction and architectural phases are controversial, with proposals for the first phase of the Peripteros ranging from the eighth century to ca. 675 B.C.⁸³¹ Anton Bammer, the excavator, continues to press for high dates.⁸³² However, the foundations of the Peripteros were modified during its

⁸²⁷ Le Roy 1967, p. 28 (R5.2/A.176).

⁸²⁸ Schädler and Schneider 2004. Also see the review by Ohnesorg 2007. I thank Michael Kerschner for his invitation to study these tiles from Ephesos. I also thank Friedrich Krinzinger and Peter Schneider for permitting the research, and I received invaluable assistance at Ephesos from Kerschner and Ulrike Muss.

⁸²⁹ Kerschner 1997, pp. 155-175, 181-182, 223; Schädler and Schneider 2004, pp. 11, 35-38.

⁸³⁰ Bammer 2001, p. 74; Kerschner 1997, p. 182; 2005, pp. 140-142; Schädler and Schneider 2004, pp. 41-44. Kerschner refutes Weissl's argument that the Peripteros went out of use during the third quarter of the seventh century B.C.: Schädler and Schneider 2004, pp. 43-44; Weissl 2002, pp. 326-327.

⁸³¹ Bammer 1990; 2004, pp. 69-76; Kerschner 2004; 2005, p. 142; Weissl 2002, pp. 321-323, 344.

⁸³² Bammer 2001; 2004, pp. 73, 77-78. Also see Weissl 2002, pp. 325-326. In support a high date, Bammer cites the Corinth and Isthmia temples as parallels on the Greek Mainland for the early

history⁸³³ significantly enough that the roof must have been reconfigured. Schädler and Schneider associate the terracotta roof with the modifications of the foundations but then argue that the Ephesian roof predated the Old Temple.⁸³⁴ Nevertheless, because the roof appears to have been installed in the second half of the seventh century B.C., their argument cannot be sustained.

The assemblage of tiles at Ephesos is oddly skewed. Although approximately 5,000 fragments were recovered, the vast majority are from pan tiles, whereas only 195 covers have been found.⁸³⁵ Two eaves pans, one ridge, two sima, and seven geison revetment tiles have been identified.⁸³⁶ Although the geison revetments and the small fragments of eaves pans are recognizable, too little remains of the ridge and sima to be certain of either identification. The profiles of the pans and covers are curved, suggesting the association with the Peaked Antefix system, although no antefix survives, and the geison tiles are idiosyncratic. The clay is distinctively local.⁸³⁷ The roof appears to be directly influenced by Peaked Antefix roofs from the Greek Mainland, where they are far more numerous, but its characteristics otherwise suggest a locally produced variant.

The roofs from Olympia, though associated with no foundations or blocks, may be dated quite early. Most tiles were recovered in sixth century contexts which correspond to the time when the two buildings were destroyed.⁸³⁸ More importantly, however, two fragments of pans from Roof 1 were found in well SO 118, which has

introduction of the peristyle. However, the temples are probably aperipteral: see above, pp. 32, 88; notes 69-70; Figure 3.2.

⁸³³ The peristyle was raised and a flanking wall was installed around the cella, substantially thickening the walls: Bammer 1990, pp. 138-142; 2001, pp. 73, 74. The stratigraphy is incompletely published, but these modifications have been dated in third quarter of the seventh century B.C.: Weissl 2002, p. 326.

⁸³⁴ Schädler and Schneider 2004, pp. 45-49. Also see Bammer 2001, pp. 73-74.

⁸³⁵ Schädler and Schneider 2004, pp. 13-14, 15, 51-58 (Cat. nos. 1-14, 30-34), Table 2.

⁸³⁶ Schädler and Schneider 2004, pp. 15-17, 54-57 (Cat. nos. 15-29).

⁸³⁷ Schädler and Schneider 2004, pp. 21, 61-69. The fabric does not resemble Mainland Greek tiles.

⁸³⁸ Seven fragments were deposited in contexts predating the mid-sixth century, and the remainder at the end of the century, with the exception of one tile from the west wall of the Stadium phase III A (460 B.C.): Heiden 1995, pp. 14-15.

been dated to the middle of the seventh century B.C.⁸³⁹ Gebhard has objected that one helmet in the fill should be dated lower, still within the third quarter of the century.⁸⁴⁰ However, the well otherwise contained much earlier material, including a near-complete oinochoe from the end of the eighth century and pottery and bronzes from within the first half of the seventh century. Despite accepting the earlier context date, Heiden places the roofs within 650-630 B.C. Apparently, he assumes that the Peaked Antefix system roofs were derived from Protocorinthian tiles and, therefore, must postdate them by some decades.

As the foregoing analysis has demonstrated, such assumptions actually reverse the chronological relationship expected from the shape and design of the tiles, with the Olympia roofs preceding those of the Corinthia. In fact, the dates of the contexts at both sites are practically indistinguishable. At Corinth and Isthmia, working chip layers have been associated with the construction of the temples, the MPC pottery providing a *terminus post quem* for construction.⁸⁴¹ A low date for the construction around the middle of the seventh century B.C. is preferable because of the architectural sophistication of both buildings. However, no Protocorinthian tiles have been recovered from contexts prior to the destruction of the Old Temple before 560 B.C.⁸⁴² At Olympia, the destruction deposits are roughly contemporary, but tiles are also recovered from the early well. The well appears to have been filled by the middle of the seventh century, thus providing the earliest context from which an architectural terracotta has been recovered. Even if the date is pushed down by two decades, the filling of the well provides only a *terminus ante quem*—confirming only that the Roof 1 tiles already existed at the time of deposition. Heiden believes that the tiles were

⁸³⁹ Heiden 1995, p. 15; Mallwitz 1999, pp. 200-201; Schilbach 1999, pp. 308-309.

⁸⁴⁰ Gebhard 2001, p. 55 note 70.

⁸⁴¹ See above, p. 36ff and note 113.

⁸⁴² See above, note 83.

damaged during construction and thrown into the well just before its filling, but this is conjectural. In fact, neither the Corinth nor the Olympia roof can be proven earlier than can the other from their contexts. Because both sequences are equally possible, the strong indications of the shape and design take priority. In all likelihood, the Peaked Antefix roof at Olympia—and perhaps also Delphi—provided the immediate inspiration for the creation of the Protocorinthian tile system at Corinth.

10.C.2) *Early tiles of Lydia and Phrygia*

Beyond the Greek world, Archaic tile-making traditions developed in Etruria and Anatolia. The roofs in Anatolia have until recently been assumed to date wholly within the sixth century B.C., although the Peaked-Antefix roof at Ephesos is securely dated within the previous century. Because the molded decorative motifs often did not change for extended periods and most of the tiles had been excavated without recorded context, the proposed dates for the introduction of tiles at other centers have fluctuated greatly. In his comprehensive study published in 1966, Åke Åkerström proposed a chronology with tile production beginning as late as ca. 560 B.C. and blossoming under Persian rule in the second half of the century.⁸⁴³

Subsequent excavations at Sardis and Gordion have shown that Åkerström's dates were too low by several decades.⁸⁴⁴ At Sardis, tiles have been recovered from stratified contexts of the mid-sixth century, and terracotta production appears to have commenced between 600 and 570 B.C. from the stylistic parallels.⁸⁴⁵ The several thousand tiles excavated at Gordion have been studied recently by Matthew R.

⁸⁴³ Åkerström 1966, pp. 239-244.

⁸⁴⁴ Glendinning 1996a, p. 102; Ö. Wikander 1992, p. 158; Winter 1993, pp. 233-254.

⁸⁴⁵ Ramage places tiles as early as 600 B.C.: Ramage 1978, pp. 38-41. Billot argues that the earliest production was ca. 570 B.C.: Billot 1980. The published contexts with tiles from Sector ByzFort are too late to resolve the disagreement: Ratté 1994b, pp. 383-385, 388.

Glendinning.⁸⁴⁶ Roof tiles first appear in Middle Phrygian layers at the site but rarely in datable contexts. Although probably Archaic manufactures, the majority of tiles were mixed in early Hellenistic debris scattered over the site.⁸⁴⁷ However, a small number of tiles were recovered from within and below the destruction layer at Küçük Hüyük associated with the Persian conquest, confirming along with stylistic comparisons that tile production was established by the first half of the sixth century B.C. at the site.⁸⁴⁸

The beginning of tile manufacturing at Gordion is uncertain. Glendinning assumes Corinth invented and disseminated roof tiles.⁸⁴⁹ He describes the possible routes of diffusion of the technology, first to Lydia, then to Gordion, although he also admits that Phrygians are as likely to have developed their roofing system independently.⁸⁵⁰ The Gordion tiles come from destruction deposits and, thus, provide no direct evidence for the time of their production and installation. Furthermore, the chronology of the site has been radically altered after recent discoveries.⁸⁵¹ The major destruction layer over the Early Phrygian buildings was formerly attributed to a Kimmerian invasion around 700 B.C., and the Middle Phrygian settlement was believed to have been rebuilt only after a long architectural hiatus. As recently as 1996, Glendinning argued that the tiles should have belonged to the first building phases in the Middle Phrygian period. In that case, the rebuilding should have been begun only in the late seventh or early sixth centuries B.C., the time when he believes

⁸⁴⁶ Glendinning 1996a; 1996b; 2002; 2005.

⁸⁴⁷ Glendinning 1996b, pp. 12, 20-28; 2005, p. 98.

⁸⁴⁸ Context evidence: Glendinning 1996a, pp. 111-115; 1996b, pp. 16-18, 46, 54, 69, 119, 139, 144. Tiles in a later deposit inside Building M may have fallen from its roof and, therefore, belong in the mid-sixth century or earlier: Glendinning 1996b, pp. 18-19, 144. Stylistic evidence: Glendinning 1996a, pp. 112-116; 1996b, pp. 42-179; 2005, p. 94.

⁸⁴⁹ Glendinning 1996a, p. 99; 2005, p. 82.

⁸⁵⁰ Glendinning 1996a, p. 116-117; 1996b, pp. 184-200.

⁸⁵¹ Summaries: DeVries 2005; DeVries et al. 2003; Voigt 2005.

tiles were introduced.⁸⁵² However, excavations revealed that the rebuilding was already underway at the end of the Early Phrygian settlement and resumed in Middle period immediately after the deposit of the destruction layer.⁸⁵³ Furthermore, new radiocarbon tests, an adjustment to samples dated by dendrochronology, and a review of stylistic parallels have firmly dated the destruction layer to the late ninth century B.C.⁸⁵⁴ As a result, no traces of the Kimmerian sack are identified, and the evidence for a subsequent hiatus in occupation has been eliminated. It now seems as if the Middle Phrygian buildings were constructed at least a century earlier than once believed and two centuries earlier than Glendinning's suggestion for tile roofs. Unfortunately, few architectural contexts may be dated firmly within the eighth and seventh centuries in the new chronology for the site. Roof tiles were found in excavations of the South Cellar, which contained stratified fills from ca. 700 B.C., but it is uncertain whether the tiles were introduced during disruptions of the sixth and fourth centuries.⁸⁵⁵

Fahri Işık has argued that Phrygian tiles should be dated much earlier on stylistic grounds.⁸⁵⁶ Concentrating on a series of well-preserved plaques from Pazarlı dated in the fifth century by Åkerström, he finds the closest parallels for the figures in East Greek art from the late seventh and early sixth centuries B.C.⁸⁵⁷ Other ornaments he associates with the rock-cut facades in the Phrygian highlands and, more generally, the geometric patterns of the Phrygian crafts from the Early and Middle periods at Gordion.⁸⁵⁸ Işık concludes that the Phrygian tiles find better parallels in early

⁸⁵² Glendinning 1996b, pp. 12-14. Because he finds no evidence that the tiles did not belong to the original buildings from the Middle Phrygian period, Glendinning suggests that the tiles could date the rebuilding.

⁸⁵³ Voigt 2005, pp. 28-32.

⁸⁵⁴ DeVries et al. 2003; Manning et al. 2001; Voigt 1994, pp. 272-273; 2005, pp. 32-35. Objections to the revised chronology have been raised: Muscarella 2003.

⁸⁵⁵ DeVries 2005, pp. 37-40.

⁸⁵⁶ Işık 1991.

⁸⁵⁷ Işık 1991, pp. 65-74. For the excavations at Pazarlı, see Koşay 1941.

⁸⁵⁸ Işık 1991, pp. 63-64, 86.

Orientalizing iconography, leading him to propose an early-seventh-century start for Phrygian tile production with a subsequent diffusion of the technology from Anatolia to Greece.⁸⁵⁹ With no clear stylistic parallels earlier than ca. 600 B.C., however, Işık's conclusions have been summarily dismissed.⁸⁶⁰ Nevertheless, his analysis does correspond to a late-seventh- or early-sixth-century introduction of roof tiles to Phrygia, the earliest date that may be sustained with certainty from the published material.⁸⁶¹ As long as the earliest securely dated terracotta tiles are in Ephesos, a Greek settlement whose roof imitates a Peloponnesian type, it must be assumed that inland Anatolians learned the craft of tile making through the Greeks.

10.C.3) *Early Etruscan tiles*

The comprehensive study of Etrusco-Italic tiles published in 1940 by Arvid Andrén placed the earliest Etruscan roofs in the sixth century.⁸⁶² However, recent excavations at two inland Etruscan sites have demonstrated that tile production emerged much earlier, in the seventh century B.C.

By far the greatest quantity of tiles from any one site was excavated at Acquarossa.⁸⁶³ First occupied between 640 and 625 B.C. and abandoned in 550-525 B.C., about a dozen clusters of houses extended for more than a kilometer along a ridge.⁸⁶⁴ The massive quantity of roof tiles recovered from the site has been thoroughly studied and published.⁸⁶⁵ At least 16 different roofs can be separated from among the painted tiles,⁸⁶⁶ and a minimum of 49 roofs can be distinguished from

⁸⁵⁹ Işık 1991, pp. 79-86. The new Gordion chronology would presumably raise the proposed date by another century.

⁸⁶⁰ Glendinning 1996a, p. 102; 1996b, p. 8; Nancy A. Winter (pers. comm. 2007).

⁸⁶¹ Glendinning 1996b, p. 185 note 9; 2005, p. 97.

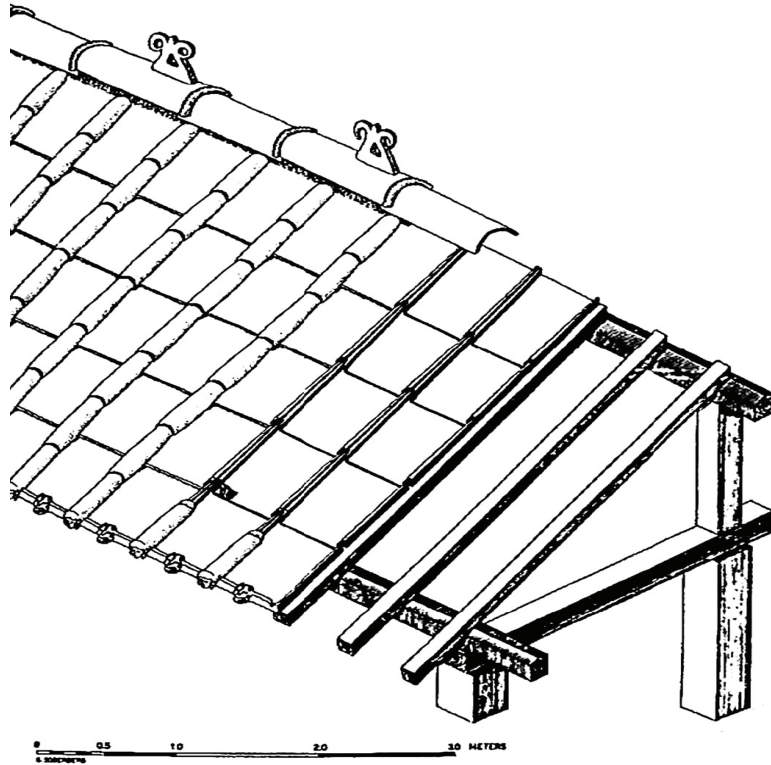
⁸⁶² Andrén 1940.

⁸⁶³ For recent bibliography, see Wikander and Wikander 1994.

⁸⁶⁴ C. Wikander 1988, pp. 119-127; Ö. Wikander 1993, p. 133.

⁸⁶⁵ Although the reason for abandonment is uncertain, the occupants left the roof tiles behind; most depredations were due to plowing: Ö. Wikander 1993, pp. 133, 136-137.

⁸⁶⁶ C. Wikander 1988, p. 48.



**Figure 10.3 Roof of the Orientalizing Workshop at Poggio Civitate
(Nielsen 1998, p. 97 fig. 2)**

among the plain tiles—more roofs than identified foundations of houses.⁸⁶⁷ Ö.

Wikander estimates the original settlement had 1,200 houses, almost all roofed with tiles for much of their history.⁸⁶⁸ Over its century-long occupation, more than a million tiles would have been produced, although the annual demand would have been relatively modest—on average, about 12,000 tiles of all varieties each season. In the absence of early stratified finds, the first tiles are dated by stylistic parallels to the time when the site was first occupied during the third quarter of the seventh century.⁸⁶⁹

All of the large buildings excavated at Poggio Civitate had tile roofs. There were two major building phases separated by a destruction layer. First was the Orientalizing Complex. The three buildings of the phase, referred to as the Workshop,

⁸⁶⁷ Ö. Wikander 1993, pp. 87-99.

⁸⁶⁸ Ö. Wikander 1993, pp. 138-139.

⁸⁶⁹ Rystedt 1983, pp. 149-155; Ö. Wikander 1993, pp. 157-158.

the Residence, and the Tripartite Building, were destroyed by a fire ca. 600 B.C. (Figure 10.3, and above, Figure 4.11).⁸⁷⁰ Afterwards, a monumental sixty-by-sixty-meter hall around a colonnaded courtyard was built. This Upper Building stood until the third quarter of the sixth century B.C., when it was systematically dismantled and the site abandoned.⁸⁷¹ Until recently, the cut-out acroteria and head-shaped antefixes and water spouts from the terracotta roofs of the Workshop and the Residence were dated no earlier than 650-630 B.C.⁸⁷² However, pottery limited to the second quarter of the seventh century was recovered from the floor of the recently excavated Tripartite Building.⁸⁷³ Tiles fallen on its floor and fragments of cut-out acroteria in the area suggest its roof was tiled in a manner similar to the Workshop and the Residence. Although the results are preliminary, the new context indicates that the Tripartite Building and perhaps the whole of the Orientalizing Complex were constructed shortly before or after 650 B.C.⁸⁷⁴

The impressive finds at the two inland sites have driven the search for seventh-century tiles elsewhere in Etruria. Tile roofs were introduced by ca. 630 B.C. to at least San Giovenale and Veii.⁸⁷⁵ None can be confidently placed before mid-century.

The argument for the derivation of Etruscan roofs from the Protocorinthian tile system has been attached to the story of Demaratus, the Corinthian merchant belonging to the Bacchiad clan.⁸⁷⁶ According to the legend, when the tyrant Kypselos overthrew the Bacchiads ca. 657 B.C., Demaratus fled Corinth to resettle in Tarquinia, marry a noblewoman, and father the fifth king of Rome. Pliny reports that Demaratus

⁸⁷⁰ See above, notes 274, 275. Before 2001, the Workshop was described in publications as the “Southeast Building,” and the Residence as the “Lower Building.”

⁸⁷¹ Nielsen and Phillips 1985; Nielsen and Tuck 2001, p. 35; Tuck 2000.

⁸⁷² Rystedt 1983, pp. 87-88, 149-155; Nielsen 1987, pp. 116-119; 1989, p. 514.

⁸⁷³ Nielsen and Tuck 2001, pp. 38-44, 46-54; Tuck 2000.

⁸⁷⁴ Nielsen and Tuck 2001, pp. 44-45; Tuck 2006.

⁸⁷⁵ Ö. Wikander 1993, p. 160, note 25. San Giovenale: Ö. Wikander 1981.

⁸⁷⁶ For bibliography, see: Ridgway 2002, p. 29 note 49; Rystedt 1983, p. 162 note 311.

brought with him three Greek modelers, “fictores,” who introduced the plastic arts to Etruria.⁸⁷⁷ Because the first architectural terracottas in Italy are identified at Acquarossa, Poggio Civitate, San Giovenale, and perhaps Veii within two or three decades of Demaratus’ flight, many scholars have hypothesized that the craftsmen taught the Etruscans the art of tile making.⁸⁷⁸ Although Pliny does not specify exactly which arts they introduced, the craftsmen are named Eucheir, Diopus, and Eugrammos, suggesting a group of skills appropriate for shaping, designing, and decorating architectural terracottas. Around 657 B.C., these craftsmen could have brought knowledge to Tarquinia of the Protocorinthian roofs at Corinth and Isthmia.

Most scholars cite this legend as confirming an early diffusion of the Protocorinthian roofing system to central Italy. At the same time, however, they find little corroboration in the material. Etruria developed hybrid system roofs with crudely shaped flat pans and narrow curved covers bearing little resemblance to the tiles of the Old Temple. Not limited to temples as in the Greek world, Etruscan tile roofs appear on ordinary houses by the time of the first settlement on Acquarossa.⁸⁷⁹ With few exceptions, the fabric and decoration of the tiles are closest to large Etruscan vases, with especially close analogues in Caeretan red-ware.⁸⁸⁰ The ridge tiles of the earliest roofs at Acquarossa and Poggio Civitate are crowned by large cut-out acroteria with uniquely Etruscan motifs.⁸⁸¹ Without parallel in Greece, the acroteria clearly hearken back to a tradition of elaborate wooden roofs which were copied in Villanovan and Etruscan house-shaped urns and rock-cut tombs.⁸⁸² The Etruscans developed many

⁸⁷⁷ Plin. *HN* 35.151-152; also Strabo 5.2.2; see above, note 788.

⁸⁷⁸ e.g., Ridgway 2002, pp. 29-31; Rystedt 1983, pp. 162-164; Ö. Wikander 1992, pp. 159-160; Williams 1980; Winter 2000.

⁸⁷⁹ Rystedt 1983, pp. 156-158; Ö. Wikander 1993, pp. 161-162.

⁸⁸⁰ Ridgway 1992; 2002, p. 3; Ridgway and Ridgway 1994, pp. 7-8; C. Wikander 1988, pp. 85-118, 131-136. Only the guilloche painted on some tiles from Acquarossa suggests Greek influence: C. Wikander 1988, pp. 100-107.

⁸⁸¹ Rystedt 1983, pp. 123-148, 159-164; 1994.

⁸⁸² e.g., Andersen 2001; Phillips 1985; Rystedt 1983, pp. 161-162; Williams 1980, pp. 349-350.

other crafts independently, casting doubt on Pliny's account of Etruscan tutelage to Greek modelers.⁸⁸³ To sustain the Demaratus narrative, scholars have offered various explanations for the lack of correspondences, such as a lack of experience making Protocorinthian tiles on the part of the migrating craftsmen or native Etruscan resistance to foreign designs.⁸⁸⁴ Others are more dismissive of Pliny's account, though generally maintaining that Corinthians inspired the Etruscans to design tiles.⁸⁸⁵

There are other reasons to doubt the technological transfer occurred at all. Etruscan buildings have comparatively light structures, with tile roofs supported on mud brick and pisé walls over low rubble foundations. Not only were the tiles relatively lightweight,⁸⁸⁶ but also, according to a recent structural analysis, the Etruscans appear to have developed some form of the tie-beam truss to reinforce their roofs (also see above, Figure 10.3).⁸⁸⁷ The unwallled Workshop at Poggio Civitate, whose roof was supported by three rows of wooden posts alone is the first building which very likely required a truss.⁸⁸⁸ Except for a few experiments in Sicily, Greek architects do not appear to have understood the principle of the truss and instead built massive stone walls to withstand the side thrust of their heavy tiled roofs.⁸⁸⁹

The two hallmarks of the Protocorinthian system, its hipped roof and combination tiles, are almost never found in Etruria. Instead, the roofs have early

⁸⁸³ Ridgway and Ridgway 1994, p. 8.

⁸⁸⁴ e.g., Rystedt 1983, pp. 162-164, especially note 311; Ö. Wikander 1992, pp. 159-160; Williams 1980; Winter 2000.

⁸⁸⁵ e.g., Ridgway 1992; 2002, pp. 29-31; Ridgway and Ridgway 1994; Phillips 1974, pp. 276-277; Ö. Wikander 1993, pp. 160-162. Beginning with Phillips, the excavators at Poggio Civitate have disputed any Protocorinthian influence on central Italic architectural terracottas.

⁸⁸⁶ Excluding the woodwork, a typical tile roof weighed close to 60 kg per square meter at Acquarossa, compared to 94 kg for the Protocorinthian tiles: Ö. Wikander 1993, pp. 128-130.

⁸⁸⁷ Turfa and Steinmayer 1996, pp. 1, 4-5, 32-34. Also see Klein 1998, pp. 334-337.

⁸⁸⁸ Turfa and Steinmayer 1996, pp. 20-21; 2002, p. 4. Also see above, note 274 and Figure 4.13. The Upper Building, too, is likely to have been roofed using a truss: Turfa and Steinmayer 1996, pp. 22-24; 2002, pp. 3-4. The truss probably was unnecessary in the smaller houses at Acquarossa: C. Wikander 1988, pp. 49-55; Ö. Wikander 1993, p. 122.

⁸⁸⁹ Klein 1998, p. 370; Turfa and Steinmayer 1996, pp. 5-8, 30-31. Probable use of the truss in Sicily: Hodge 1960, pp. 17-24; Klein 1998, pp. 346-352, 357-358, 368-370; also see Hellmann 2002, p. 289.

instances of *simas*, large convex ridge tiles, and revetment plaques at the eaves. The Etruscans had a radically different approach to monumentality. The Protocorinthian tiles are distinguished from the ordinary by their scale, thickness, fine polished slip, and geometrical unity from eaves to ridge. Although the buildings of Poggio Civitate were of monumental proportions, the individual tiles of the roofs were relatively small, lightweight, coarsely finished, and irregular. Instead, the Etruscan designers invested their attention in exuberant plastic decoration at the eaves and ridge.

In review, the Protocorinthian and Etruscan tile systems share so little in common that they should be considered to have had independent origins. Of the seventh-century roofing systems reviewed this far, the Etruscan hybrid roofs are the least similar to Protocorinthian roofs. The idea of tile making may have been transferred by word of mouth from one region to the other, but no craftsmen with tile-making experience could have been involved. The artisans accompanying Demaratus cannot have made any meaningful impact on Etruscan designers. Therefore, the chronological marker of ca. 657 B.C. implied by Pliny's narrative should be separated from the problem of early tile production.

As with the first Peaked Antefix system roofs at Olympia, the excavated evidence does not clearly support the preeminence of the Corinthians over the Etruscans in the invention of ceramic roof tiles. Although not yet adequately published, the floor of the Tripartite Building at Poggio Civitate contained objects of equivalent date to the construction fills associated with the Corinth and Isthmia temples. Even earlier tiles have been identified recently at Veii. Inside four tombs of the Quattro Fontanili cemetery, several alcove burials with eighth-century goods had been sealed by pan tiles of the first types at Acquarossa.⁸⁹⁰ It seems unlikely that the tombs were entered in the seventh century or later to add the pan tiles. Outside of an

⁸⁹⁰ Andersen and Toms 2001.

architectural context, however, the pan tiles are an inadequate basis for extending the Etruscan tradition of tile making back by more than fifty years.

The designs of Etruscan tiles are simple. Except for their flanges, the flat pans with raised rims closely resemble Mycenaean pan tiles. The similarities to Late Helladic pans do not reflect continuity but rather functionality. The pans are the simplest clay shape conceivable for channeling water—a flat slab with rims to prevent water from escaping out the sides and some accommodation for overlap. The tapered, vaulted covers are the most direct means of covering the gap between adjacent vertical rows of pans. The vaulted profile is the most efficient use of material for fitting over the vertical rims of adjacent pans. In comparison, a gabled Corinthian-style cover of the same overall dimensions is harder to shape, prone to break along its peak, and less flexible during installation. In other words, the Etruscan roofs are simpler than Protocorinthian or even Peaked Antefix system roofs and, therefore, appear closest to a hypothetical point of invention for the technology. The Etruscan roofs were also efficient. The Romans changed only details of the design, and the methods for shaping covers at Poggio Civitate appear to have survived largely unchanged until the modern era.⁸⁹¹

10.D) Conclusions

The purpose of this extended review of early tile-production centers is not to propose another evolutionary sequence, akin to Schwandner's hypothetical stages leading up to the Protocorinthian system, or a theory of spontaneous invention, like Wikander's wooden-shingles hypothesis. An explanation of an ancient technology must be grounded in the evidence, which in this case is insufficient to make a final determination. The analysis depends first on the context of the finds and second on the

⁸⁹¹ See above, notes 267, 269.

methods of production. Although the construction deposits of the temples at Corinth and Isthmia still indicate that Protocorinthian tiles are the first excavated, the chronological separation from Roof 1 at Olympia, the Orientalizing Complex at Poggio Civitate, and perhaps the roof at the Artemision of Ephesos is negligible.

However, some relationships among the early systems are clear from the second criterion, the technique. The Protocorinthian roofing system is very unlikely to have been the prototype for all other tile roofs. Its combination tiles must have imitated a predecessor with separated covers and pans, and its design appears to have directly improved on the system represented by the Olympia roof. Too complex, inefficient, and austere to have inspired many imitators, the Protocorinthian system is best explained as an offshoot of the Olympia-type roof. This is a reversal of the traditional model with Corinthians in the lead. However, the Corinthians appear to have been open to change throughout the Archaic period. Although the tile makers maintained the high production standards and geometric regularity of the Protocorinthian roofing system in the tiles they produced in the sixth century, they incorporated innovations from other regions. They adopted brightly-painted stamped decoration at the eaves, they replaced hipped roofs with a gable, they added a raking sima with lion-head water spouts resembling earlier North-Western Greek roofs, and they crowned the roof with palmette and sphinx acroteria in the manner of the first Etruscan roofs.

The concentration of many Peaked Antefix roofs in the northeast Peloponnese and their wide geographic distribution suggest the original Mainland Greek roofing technology was of this type. A true hybrid, the curved covers and pans could have inspired the perfectly circular Laconian tiles. Yet at the same time, the curvature of the pans was slight enough that they could be formed on a flat surface, as with the Etruscan hybrid pans. The Protocorinthian tiles could have been converted from this

system by a single decision: molding covers and pans in combination. This decision at Corinth may have been motivated by practicality. Every cover of the Olympia roof was equivalent to the free covers of the Old Temple, but no holes for fastening by nails are found in the tiles of Olympia Roof 1. The fact that the designers at Corinth took the trouble to nail the free covers in place suggests that shifting position was problem for the covers like those of Roof 1. Moreover, the heavily chiseled hip covers at Olympia weighed only about four kilograms and, thus, would have been particularly vulnerable to dislodging by powerful storms. When adopting combination tiles, the Corinthians may have been reacting to the problem of wind encountered by early experimental designs such as Roof 1 at Olympia. Of course, securing the tiles was crucial. Any storm damage to the expensive terracotta roof was not just an inconvenience to repair but, even worse, a sign of displeasure from the gods.

I have argued that, even without prior experience of tile making, the Corinthian potters could have invented the Protocorinthian tile system by imitating a foreign terracotta roof. However, this explanation is unnecessary, because the close resemblance of the Peaked Antefix and Protocorinthian roofs suggests a common designer instead. A craftsman who had worked on the production of a Peaked Antefix roof must have brought the technology to the Corinthians. However, once the Corinthians had developed their monumentalized version of the Peaked Antefix system, the two traditions stayed distinct from one another, as if the Protocorinthian tile system were maintained by separate craftsmen after the invention at the Old Temple.

The early Peaked Antefix roofs may have been developed without antecedents. However, terracotta roofs were also established early in southern Etruria. By the second half of the seventh century, the Etruscans had developed tile-making techniques which survived largely unaltered for more than twenty-six centuries into

the modern era.⁸⁹² They mass produced tiles for palatial halls as well as common houses, imitating the elaborate wooden acroteria from Villanovan architecture. It can hardly be a coincidence that both Greeks and Etruscans began producing terracotta tiles at almost the same time. Although they do not appear to have exchanged any designs or production techniques, one group must have taken from the other the general idea of covering roofs in interlocking ceramic tiles. From the present evidence, it is clear that either the southern Etruscans or the north-Peloponnesian Greeks invented the terracotta tile roof.

⁸⁹² See above, Chapter 4, and Ö. Wikander 1993, pp. 104-109, 121-123, 137-139.

APPENDIX CATALOGUE OF TILES

This catalogue includes all of the Protocorinthian tiles inventoried from the Old Temple at Corinth.⁸⁹³ The tiles from Isthmia, Delphi, Perachora, and the Sanctuary of Demeter and Kore at Corinth have already been published.⁸⁹⁴ The significant variations of other Protocorinthian tiles from the Old Temple system have been discussed in Chapter 9. Readers should refer to Chapter 3 for a description and illustrations of the Protocorinthian tile system.

General conventions

Many tiles have been mended from multiple fragments. When this is the case, the number of fragments is noted. Because plaster had been used to patch many of the joins made during early restorations, often it is impossible to determine into how many pieces the tile had broken with certainty.

L.: Longitudinal dimension, from left to right

W.: Transverse dimension, from front to back

Th.: Thickness of the tile, that is, the shortest distance between the top and bottom faces at a given point. Note that all thickness measurements are approximate, as the thickness of the tile varies throughout.

Attached side: The inner side of the cover or pan, where the cover and pan adjoin

Free side: The unattached side of the cover or pan

⁸⁹³ I thank Robin F. Rhodes for his permission to include the unpublished tiles from the Old Temple at Corinth, which he is publishing as part of a monograph on the building: see above, note 92.

⁸⁹⁴ However, some tiles that have been recently inventoried for the restudy at Isthmia by Hemans are unpublished: see above, notes 97, 198, and 212.

Horizontal row: Each course of tiles, as constructed in succession from eaves to ridge

Vertical row: The consequent alignment of individual tiles from one horizontal row to the next, running up the slope of the roof from eaves to ridge

Finished surfaces: The top surfaces, the front face, and the lateral cover faces of every tile which were visible from the exterior of the building

Unfinished surfaces: The back face, the lateral face of the pan, and the undersides of every tile which were invisible from the exterior of the building

Bevel: A diagonal cutting (when viewed in plan) in the corner of a combination tile required to accommodate a diagonally adjacent tile in the roof grid

Cover bevel: The bevel at the back free corner of a cover

Pan bevel: The bevel at the front free corner of a pan

Notch: The rectangular cutting at the back attached corner of a cover

Cover rabbet: The cutting along the underside of the free edge of the cover

Pan rabbet: The cutting along the underside of the front edge of the pan

Transverse overlap: The portion of the upper surface of the tile that is overlapped by the tile above

Lateral overlap: The portion of the upper surface of the tile at the free end of the pan that is overlapped by the next tile in its horizontal row

REGULAR COMBINATION TILES

Rear overlap: The intended and actual overlaps of the tile above are indicated by incised lines and weathering marks near the back edge of the tile's upper surface. The actual maximum overlap may be represented by the width of the pan rabbet on the tile above.

Lateral overlap: The intended and actual overlaps of the next tile in the horizontal row are indicated by incised lines and weathering marks near the free end of the pan's upper surface. The maximum overlap may be represented by the length of the cover rabbet on the adjacent tile.

OT 1) FC 29

Mended from 4 fragments
Weight 9.9 kg
Pres. L. 35.9 cm, Pres. W. 51.1 cm, Th. ca. 3 cm (cover interior)
Cover: L. 24.8 cm
Lateral overlap: Cover rabbet L. 13.0-13.7 cm

This fragment preserves the full longitudinal dimension of the cover and the attached side of the pan of a left-handed combination tile.

OT 2) FP 76

Mended from ca. 10 fragments
Weight 19.1 kg
Pres. L. 56 cm, W. 65.2 cm, Th. ca. 3 cm (pan front edge)
Pan: Total L. 44.4 cm, Exposed L. 30.7 cm (to incised line and weathering), Exposed W. 56.3-57.5 cm (to incised line), Exposed W. 57.1 cm (to weathering)
Lateral overlap: Incised line 13.7 cm
Rear overlap: Pan rabbet W. 9.9-10.8 cm, Notch W. 7.3-7.6 cm, Incised line 7.9-8.4 cm, Weathering 7.9-8.1 cm

This is a fragment of the cover and pan of a right-handed combination tile. The entire width of the tile is preserved, and the free edge of the pan is intact at the front corner.

The transverse dimension of the notch was increased by post-firing trimming, although the notch was still too shallow to allow the next tile above to overlap as far as the incised line. A faint line of weathering indicates that the next tile above reached only as far as the face of the notch.

The pan rabbet is intact and was not chiseled back after firing. Only the inside edge of the cover rabbet remains, which was entirely cut before firing. The pan rabbet was roughly chiseled.

OT 3) FC 80

No mends
Weight 0.9 kg
Cover: Pres. L. 11.6 cm, Pres. W. 15.2 cm, Th. ca. 3 cm (cover front edge)

This fragment preserves the front free corner of a left-handed combination tile. The cover rabbet was chiseled back after firing to fit the cover bevel of the tile below.

OT 4) FP 103

Mended from 7 fragments
Weight 5.5 kg
Pres. L. 23.0 cm, Pres. W. 50.1 cm, Th. ca. 4 cm (pan edges and interior)
Lateral overlap: Incised line 14.2 cm, Weathering 14.3 cm

This fragment preserves the free side of the pan of a right-handed combination tile.

After firing the pan bevel was widened longitudinally ca. 4 cm in order to accommodate the cover bevel of the tile diagonally adjacent in the row below and to the left. This effectively increased the lateral overlap zone of the pan, which at 14.3 cm is unusually long.

OT 5) FP 110

Mended from ca. 12 fragments
Weight 14.1 kg
Pres. L. 0.467 cm, W. 65.3 cm, Th. ca. 3-4 cm
Cover: Exposed W. 55.0 cm (to incised line and weathering)
Pan: Exposed W. 54.8 cm (to weathering)
Rear overlap: Bottom Rabbet) 12.4-12.9 cm, Notch W. 9.8 cm, Incised line 9.7-9.8 cm, Weathering 9.5-9.9 cm

The full transverse dimension and the attached sides of the cover and pan of this right-handed

combination tile are preserved. The tile has been extensively mended and filled with plaster, meaning some of the transverse dimensions are unreliable.

The transverse dimension of the notch was extended by chiseling to the intended and actual overlaps indicated by the incised lines and the weathering marks.

The pan rabbet was chiseled heavily after firing. The inner margins of the cover rabbet preserve some of the original pre-firing tooling.

OT 6) FC 111

No mends

Weight 0.7 kg

Pres. L. 15.2 cm, Pres. W. 13.8 cm, Th. ca. 3 cm (front and lateral edges)

This fragment preserves the front free corner of a right-handed combination tile. The cover rabbet was cut after firing to fit over the cover bevel of the tile below.

Long striations from pre-firing tooling are preserved on the interior of the cover rabbet. Along the front edge, a bedding was cut after firing which would fit over the back side and cover bevel of the tile below. The lateral edge of the cover rabbet was chiseled down as well.

OT 7) FC 112

No mends

Weight 1.4 kg

Pres. L. 14.2 cm, Pres. W. 12.6 cm, Th. ca. 3 cm (cover front edge)

Rear overlap: Cover rabbet W. 8.3-8.4 cm

This fragment preserves the front face at the midpoint of a right-handed combination tile. The finished surfaces are coated in a dark black paint with a few splotches that fade to pale tan.

Long striations from pre-firing tooling are preserved on the interior of the cover rabbet. Along the front edge, a bedding was cut after firing which would fit over the back side and cover bevel of the tile below. The free side of the cover rabbet was chiseled down as well.

OT 8) FP 155

Mended from ca. 22 fragments

Weight 25.7 kg

L. 65.4 cm, W. 64.6 cm, Th. ca. 3 cm (pan front edge)

Cover: L. 25.2 cm, Exposed W. 55.3 cm (to weathering)

Pan: Total L. 42.0 cm, Exposed L. 30.5 cm (to weathering), Exposed W. 55.3 cm (to weathering)

Lateral overlap: Weathering ca. 9.1 cm

Rear overlap: Pan rabbet W. 7.7-9.5 cm,

Notch W. ca. 10.0 cm, Incised line W. ca. 9.5 cm, Weathering W. ca. 9.5 cm

This right-handed combination tile is nearly intact.

The transverse dimension of the notch is greater than the intended overlap suggested by the incised setting line along the back of the cover and pan. A weathering line coincides with the overlap indicated by the notch. The back face of the tile, however, is damaged, so the exact rear overlap dimensions are uncertain. The free side of the pan was roughly cut back with a broad blade, probably after firing.

Both the cover and pan rabbets were heavily chiseled with a narrow blade after firing. The inner margins of the cover rabbet also preserve some of the original pre-firing tooling.

OT 9) FP 157

Mended from ca. 9 fragments

Weight 19.4 kg

Pres. L. 58.0 cm, W. 65.0 cm, Th. ca. 3 cm (pan front edge)

Cover: L. 24.6 cm, Exposed W. 56.5 cm (to weathering)

Pan: Exposed L. 32.2 cm (to incised line, weathering)

Rear overlap: Pan rabbet W. 11.2-13.1 cm,

Notch W. 8.7 cm, Weathering 7.9-8.2 cm

This is a fragment of the cover and pan of a right-handed combination tile. The full length and width of the cover are preserved.

With a longitudinal dimension of only 1.9-2.8 cm, the notch is abnormally narrow, and it was not widened after firing. This may be a consequence of the unusually narrow cover (whose length is 0.4 cm below average): a consistent dimension from the free edge of the cover to the notch would result in a narrower notch for a narrower cover tile. The upper surface of the cover was hacked down along its back edge after firing. Two incised lines suggesting the intended lateral overlap were cut into the upper surface of the pan near its free end, the left one aligned with a faint weathering mark.

The pan bevel is preserved near the front edge, and the cover bevel is intact. Both bevels were chiseled. All of the pan rabbet and the outer margins of the cover rabbet were chiseled after

firing. However, long striations on the rest of the cover rabbet left by pre-firing tooling reveal that the rabbet was first cut before firing.

OT 10) FP 158

Mended from 4 fragments
Weight 17.0 kg
Pres. L. 40.0 cm, W. 65.0 cm, Th. ca. 5 cm (cover)
Cover: L. 25.0 m, Exposed W. 53.7 cm (incised line)
Pan: Exposed W. 53.7 cm (incised line)
Rear overlap: Pan rabbet W. 11.7-12.2 cm, Notch W. 11.2 cm, Incised line 11.1-11.8 cm

This is a fragment of the cover and pan of a right-handed combination tile. The full width of the tile and length of the cover are preserved.

The finished surfaces of the tile are coated with black paint with the exception of its back edge. The paint is consistently dark gray except near the back edge, where it fades to a streaky reddish orange—probably due to the thinning of its application. The paint is heavily abraded, exposing the pale tan slip below it.

The rear overlap indicated by the incised lines and the notch coincide. The transverse dimension of the notch was expanded after firing through chiseling.

All of the pan rabbet and the outer margins of the cover rabbet were chiseled after firing. However, long striations on the rest of the cover rabbet left by pre-firing tooling reveal that the rabbet was first cut before firing.

OT 11) FP 164

Mended from 4 fragments
Weight 16.6 kg
Pres. L. 46.8 cm, Pres. W. 58.0 cm, Th. ca. 4 cm (cover and pan interior)
Cover: L. 25.0 cm
Lateral overlap: Cover rabbet L. ca. 14
Rear overlap: Notch W. 8.1 cm, Incised line 7.8-8.7 cm, Weathering 8.1-8.6 cm

This fragment preserves the back and attached side of the pan and the back side and full length of the cover of a right-handed combination tile.

The notch was cut out before firing and not retooled afterwards. Its transverse dimension coincides with the intended and actual overlaps indicated by the incised lines and weathering. The cover bevel was not retooled after firing.

Long striations on the surface of the cover rabbet were left by pre-firing tooling, and its inner and outer margins were chiseled afterwards. The pan rabbet was cut after firing.

OT 12) FT 210

Mended from ca. 14 fragments
Weight 30.5 kg
L. 66.9 cm, W. 65.0 cm, Th. ca. 3 cm (pan front edge)
Cover: L. 25.2 cm, Exposed W. 53.8 cm (to incised line), Exposed W. 53.5 cm (to weathering line)
Pan: Total L. 41.6 cm, Exposed L. 31.7 cm (to incised line), Exposed L. 32.0 cm (to weathering), Exposed W. 54.1 cm (to weathering line)
Lateral overlap: Incised line 9.8-10.0 cm, Weathering 9.6-9.8 cm
Rear overlap: Pan rabbet W. 11.5-13.2 cm, Notch W. 10.6 cm, Incised line 10.9-11.2 cm, Weathering 10.6-0.10.9 cm

All but the front face of this left-handed combination tile is intact.

The weathering line near the back edge of the cover and pan indicates that the next tile above did not overlap as far as the incised line. Instead, it reached as far as the face of the notch, whose transverse dimension had been enlarged after firing. A strip along the upper free edge of the pan was roughly hacked down to fit under the cover of the next tile in the horizontal row.

An incised line in the upper surface of the cover runs along the edge of its corner bevel and appears to be a guideline for its cutting. Such lines are seldom preserved. Both the cover and pan bevels were chiseled back after firing.

Several impressions of fingertips are preserved in the unfinished sides of the tile: five on the free face of the pan near the back, and at least four on the back face at the junction of the cover and pan. The impressions are grouped along the bottom edge of both of these faces.

The bottom is rough and discolored, and a few small lumps of gray material have been baked onto the surface. Both underside rabbets are heavily chiseled, though long striations from pre-firing tooling on the cover rabbet were left intact along its inner margins.

OT 13) FT 224

Mended from ca. 12 fragments
Weight 28.6 kg

L. 66.8 cm, W. 64.8 cm, Th. ca. 3 cm (pan front edge)
 Cover: L. 24.8 cm, Exposed W. 55.3 cm (to incised line and weathering)
 Pan: Total L. 41.9 cm, Exposed L. 30.4 cm (to incised line), Exposed W. 55.3 cm (to incised line and weathering)
 Lateral overlap: Cover rabbet L. ca. 13 cm, Incised line 11.2-11.6 cm
 Rear overlap: Pan rabbet W. 7.1-8.6 cm, Notch W. 9.2 cm, Incised line and weathering 9.3-9.6 cm

This right-handed combination tile is nearly intact.

The finished surfaces of the tile are coated with black paint with the exception of an unpainted band along the back edge of the upper surface. The paint is predominantly gray but in patches is faded to a dull orange-brown. This is perhaps due to an uneven application of the paint. A faded orange wash extending beyond the outer edge of the darker paint into the areas of the lateral and rear overlaps represents the first of several layers of paint applied to the finished surfaces of the tile. The paint is heavily abraded, exposing the pale tan slip below it.

The notch face and the longitudinal incised lines and weathering all coincide in their indication of the overlap for the next tile above. Typical weathering patterns do not form on the black paint, but the area of overlap has been abraded by the tile above.

Two finger impressions are preserved in the free end face of the pan near the junction with the pan bevel. The cover and pan bevels were chiseled back after firing, but striations at the center of the cover rabbet are more consistent with pre-firing tooling.

Both rabbets were heavily chiseled, though long striations from pre-firing tooling on the cover rabbet were left intact along its inner margins.

OT 14) FT 228

Mended from ca. 8 fragments
 Weight 19.7 kg
 Pres. L. 54.0 cm, W. 64.7 cm, Th. 4.3 cm (pan at rabbet)
 Pan: Total L. 38.4 cm, Exposed L. 26.3 cm, Exposed W. 55.3 cm (to incised line), Exposed W. 55.2 cm (to weathering)
 Lateral overlap: Weathering 11.6-12.5 cm
 Rear overlap: Pan rabbet W. ca. 9 cm, Notch W. 12.5 cm, Incised line 11.0 cm

The front face of the pan and most of the cover are broken away from this right-handed combination tile. At the center of the reassembled tile, however, is one of the largest unbroken fragments preserved from the temple, with dimensions of roughly L. 50 cm by W. 55 cm

No weathering line is preserved to indicate the actual overlap of the tile above, and the overlaps indicated by the notch and the incised line do not coincide. The face of the notch was cut back after firing considerably beyond the incised line.

The total and exposed lengths of the pan are unusually short, and its free end was cut back with a broad blade, probably after firing. This suggests the probability that the tile was cut down for an unusually narrow space on the roof, perhaps due to a misalignment in the rows below or due to the accommodation of the error of the lateral overlaps of the tiles accumulated as they were laid from the hip rafter toward the center of a given side. A faint weathering stain on the front face at the pan-cover joint seems to mark the position of the notch of the tile below.

A short portion of the pan rabbet is preserved, heavily tooled throughout after firing. The inner margin of the cover rabbet was not worked after firing.

OT 15) FP 306

No mends
 Weight 3.1 kg
 Pres. L. 24.8 cm, Pres. W. 25.0 cm, Th. ca. 5 cm (pan interior)

This fragment preserves the attached side and the inner margins of the rabbet of the pan of a right-handed combination tile.

OT 16) FP 316

No mends
 Weight 1.5 kg
 Pres. L. 18.5 cm, Pres. W. 21.6 cm, Th. ca. 3 cm (cover front edge)
 Rear overlap: Cover rabbet W. 10.8 cm

The front free corner is preserved from this left-handed combination tile. The finished surfaces of the tile are coated with grayish brown paint which has been abraded in many areas down to the pale buff slip.

Long striations from pre-firing tooling are preserved on the interior of the cover rabbet, but along the front edge, a bedding was cut after firing which would fit over the back side and cover bevel of the tile below. This bedding allowed this tile to

fit ca. 1 cm lower on the tile below. The bedding is an unusually clear indicator of the rear overlap due to its neatly trimmed edges.

OT 17) FP 325

Mended from 2 fragments

Weight 4.5 kg

Pres. L. 27.8 cm, Pres. W. 26.8 cm, Th. ca. 4 cm (cover front edge)

Cover: L. 25.4 cm

Lateral overlap: Cover rabbet L. 12.3 cm

Rear overlap: Pan rabbet W. 10.2-11.0 cm

This fragment preserves the front end and the attached side of a left-handed combination tile.

Remnants of dark black paint adhere to the finished faces of the tile. The paint has streaks of pale brown on its side faces.

The cover and pan rabbets were chiseled after firing, but long striations from pre-firing tooling are preserved on the interior of the cover rabbet.

OT 18) FP 327

No mends

Weight 5.5 kg

Pres. L. 26.9 cm, Pres. W. 35.9 cm, Th. ca. 3-4 cm (cover interior)

Cover: L. 24.8 cm

Rear overlap: Cover rabbet W. 11.0-11.7 cm

This fragment preserves the front end and the attached side of the pan of the left-handed combination tile.

The tile has the unusual omission of any cuttings for the lateral overlap zone of the cover rabbet. Instead, the front edge of the cover was cut back only after firing to accommodate the cover bevel and back end of the tile below.

OT 19) FP 328

Mended from 2 fragments

Weight 2.1 kg

Cover: Pres. L. 15.7 cm, Pres. W. 34.1 cm, Th. ca. 2-3 cm (cover edges)

Rear overlap: Cover rabbet W. 9.4-9.5 cm

This fragment preserves the front right corner of a right-handed combination tile.

Long striations from pre-firing tooling are preserved on the interior of the cover rabbet.

Along the front edge, a bedding was cut after firing which would fit over the back side and cover bevel of the tile below. This bedding allowed this tile to fit ca. 1 cm lower on the tile below. The free edge of the cover rabbet was hacked down after firing.

OT 20) FP 329

No mends

Weight 2.7 kg

Pres. L. 19.0 cm, Pres. W. 28.0 cm, Th. 4 cm (cover front edge)

Lateral overlap: Cover rabbet ca. 13 cm

The front free corner of the cover is all that is preserved of this right-handed combination tile.

The original pre-firing cuttings of the cover rabbet were left largely intact. The rabbet was cut to a consistent plane except along its front and free edges, forming a lip ca. 3-4 cm wide and ca. 0.5 cm high. The floor of the rabbet was scraped smooth before firing. There was some chiseling along the front lip of the rabbet to accommodate the tile below.

OT 21) FP 333

No mends

Weight 5.5 kg

Pres. W. 26.4 cm, Pres L. 32.9 cm, Th. ca. 4 cm (cover front edge)

Lateral overlap: Cover rabbet L. 12.1-12.2 cm

Rear overlap: Pan rabbet W. 11.4-11.8 cm

This fragment preserves the front end of a left-handed combination tile. The majority of the cover rabbet was cut before firing except for the chiseling along its outer margins.

OT 22) FP 337

No mends

Weight 0.75 kg

Pres. L. 16.8 cm, Pres. W. 11.6 cm, Th. ca. 4 cm (cover and pan front edge)

This fragment preserves the front face of the attached sides of the cover and pan of a right-handed combination tile. The cover and pan rabbets were both retooled after firing.

EAVES COMBINATION TILES

Fascia transverse overlap: The actual maximum overlap for the fascia board at the front permitted by the pan rabbet.

Back transverse overlap: As the regular tile transverse overlap, excluding the pan rabbet.

Lateral overlap: As the regular tile lateral overlap.

OT 23) FC 63

No mends

Weight 3.2 kg

Pres. L. 18.2 cm, Pres. W. 20.9 cm

This fragment preserves the attached sides of the cover and pan of a right-handed eaves combination tile near its front face.

Rear overlap: Notch W. 10.2 cm, Incised line 10.8-11.0 cm, Weathering 9.1 cm

This fragment preserves the back face and attached side of the cover and the attached side of the pan from a right-handed combination eaves tile. The back corner of the cover bevel is preserved.

OT 24) FC 64

No mends

Weight 2.0 kg

Pres. L. 13.7 cm, Pres. W. 20.3 cm

Fascia transverse overlap: Pan rabbet W. 4.0 cm

This fragment preserves the attached sides of the cover and pan of a right-handed eaves combination tile at its front face.

OT 28) FP 160

No mends

Weight 2.4 kg

Pres. L. 14.5 cm, Pres. W. 24.5 cm, Thickness 7.7 cm (pan front free edge)

Lateral overlap: Incised line and weathering 11.6 cm

Fascia transverse overlap: Pan rabbet W. 5.3-5.6 cm

This fragment preserves the front free corner of a right-handed combination eaves tile.

OT 25) FC 81

No mends

Weight 2.0 kg

Pres. L. 20.4 cm, Pres. W. 10.8 cm

Fascia transverse overlap: Pan rabbet W. 4.2 cm

This fragment preserves the attached sides of the cover and pan of a left-handed eaves combination tile at the front face of the cover.

OT 29) FP 161

No mends

Weight 2.0 kg

Pres. L. 12.9 cm, Pres. W. 21.3 cm, Thickness ca. 6 cm (near pan front free edge)

This fragment preserves the free face near the front edge of a left-handed combination eaves tile. The back edge of the pan rabbet is intact.

OT 26) FC 82

No mends

Weight 0.8 kg

Pres. L. 14.9 cm, Pres. W. 14.9 cm

This fragment preserves the front face of the cover of a left-handed eaves combination tile.

OT 30) FP 162

No mends

Weight 2.1 kg

Pres. L. 16.1 cm, Pres. W. 19.4 cm, Thickness 7.2 cm (pan front free edge)

Lateral overlap: Weathering 12.4-13.4 cm

Fascia transverse overlap: Pan rabbet W. 4.5 cm

This fragment preserves the front free corner of a left-handed combination eaves tile. The lateral face of the pan was chiseled along the front edge, but behind are four horizontal grooves which

OT 27) FC 86

Mended from 6 fragments.

Weight 6.9 kg

Pres. L. 32.4 cm, Pres. W. 55.5 cm, Thickness ca. 4 cm (pan interior)

appear to be the impressions of fingers dragged along the side before the clay had dried leather hard.

OT 31) FP 163

No mends
Weight 6.1 kg
Pres. L. 34.2 cm, Pres. W. 45.8 cm, Thickness ca 4 cm (pan interior)
Fascia transverse overlap: Pan rabbet W. 5.0 cm

This fragment preserves the front face of the pan and the attached side of the cover of a left-handed eaves combination tile.

The pan rabbet and the inner face of the cover rabbet were retooled after firing. The underside of the pan was lightly chiseled behind the pan rabbet where it might have rested on a transverse timber.

OT 32) FP 165

No mends
Weight 1.4 kg
Pan: Pres. L. 19.5 cm, Pres. W. 17.2 cm, Thickness ca 4 cm (pan interior)
Fascia transverse overlap: Pan rabbet W. 5.2 cm

This fragment preserves the front face of the pan of an eaves combination tile with uncertain handedness.

OT 33) FT 201

No mends
Weight 1.1 kg
Pres. L. 13.5 cm, Pres. W. 11.1 cm
Fascia transverse overlap: Pan rabbet W. ca. 6 cm

This fragment preserves the attached sides of the cover and pan at the front face of a left-handed eaves combination tile. Remnants of paint on the finished surfaces show the tile was painted black.

OT 34) FT 209

Mended from ca. 9 fragments
Weight 25.0 kg
L. 68.5 cm, W. 65.5 cm, Thickness 2.9 cm (pan front edge minimum), 6.7 cm (pan front free edge maximum), 7.0 cm (pan front attached edge maximum)
Cover: L. 24.7 cm, Exposed W. 56.9 cm (to weathering)
Pan: Total L. 43.6 cm, Exposed L. 30.6 cm (to incised line), Exposed L. 30.8 cm (to

weathering line), Exposed W. 57.7 cm (to incised line)

Lateral overlap: Cover rabbet L. ca. 12 cm, Incised line 12.9-13.0 cm, Weathering 12.3-13.0 cm

Back transverse overlap: Notch W. 9.4 cm, Incised line 7.4-8.4 cm, Weathering 8.6 cm

Fascia transverse overlap: Pan rabbet W. 4.3-4.6 cm

This is a right-handed eaves combination tile with full length and width preserved. The back free corner of the pan, the back end of the cover, and the front free corner of the cover have been restored in plaster.

The notch faces were cut only before firing, although what appears to be a second bevel was cut after firing into the back attached corner of the cover, where it intersects with the right face of the notch. In this position, the bevel is superfluous for normal tile interlocking, but it is possible that it had been cut to fit the pan bevel of a left-handed regular tile set in the row above. In that case, the handedness of tiles was not always consistent within each vertical row, and the free covers were not all placed on the same vertical row. Some free cover tiles preserve a second cover bevel, but FT 217 is the only other combination tile with a second bevel.

The cover is set back ca. 1.4 cm from the front face of the pan. The upper face of the pan was hacked down along its free edge after firing. The free face of the pan was retooled after firing only near its front edge, where it would have fitted flush against the neighboring eaves pan.

The underside rabbets were retooled after firing. The underside of the pan was lightly chiseled behind the pan rabbet where it might have rested on a transverse timber.

OT 35) FT 211

Mended from ca. 11 fragments
Weight 20.0 kg
L. 70.3 cm, W. 65.8 cm, Thickness 2.3 cm (pan front edge minimum), 7.3 cm (pan front free edge maximum), 6.3 cm (pan front attached edge maximum)
Cover: L. 24.9 cm
Pan: Total L. 43.7 cm, Exposed L. 33.5 cm (to weathering line)
Lateral overlap: Cover rabbet L. ca. 13 cm, Weathering 10.0-11.5 cm
Fascia transverse overlap: Pan rabbet W. 4.8-5.2 cm

This is a left-handed eaves combination tile. The front free corner of the cover and back side of the tile except for a single fragment at the free corner of the pan have been restored in plaster.

The cover is set back ca. 0.8 cm from the front face of the pan. The upper face of the pan was hacked down along its free edge after firing. Several finger impressions are preserved on the lower edges of the lateral and back faces of the pan.

The cover rabbet was chiseled after firing, although long striations along inner margins of the cover rabbet reveal that it was first cut before firing. The pan rabbet appears to have been cut out largely before firing, exposing some voids in the core of the tile. The underside of the pan was lightly chiseled behind the pan rabbet where it would have rested on a transverse timber.

OT 36) FT 233

No mends

Weight 0.5 kg

Pres. L. 10.2 cm, Pres. W. 12.2 cm, Thickness ca. 6 cm (near pan front free edge)

This fragment preserves the free side of the pan near the front edge of a left-handed eaves combination tile. Remnants of cracked black paint adhere to the upper surface.

OT 37) FT 234

No mends

Weight 1.9 kg

Pres. L. 13.3 cm, Pres. W. 21.0 cm

This fragment preserves the free side of the pan near the pan rabbet of a right-handed eaves combination tile. A faded brown paint adheres to the upper surface.

OT 38) FT 235

No Mends

Weight 3.4 kg

Pres L. 19.6 cm, Pres W. 29.4 cm, Thickness ca. 6 cm (near pan front free edge)

Lateral overlap: Weathering 13.0-13.3 cm

This fragment preserves the free side of the pan near the front edge of a right-handed eaves combination tile.

OT 39) FT 236

No mends

Weight 3.8 kg

Pres. L. 20.9 cm, Pres. W. 22.5 cm, Thickness 6.4 cm (pan front attached edge maximum)

Fascia transverse overlap: Pan rabbet W. 6.1 cm

Only the front right corner of the cover and a small section at the front face of the pan are preserved from this left-handed eaves combination tile.

The cover is set back ca. 1.4 cm from the front face of the pan. The intact portions of the cover and pan rabbet faces have been chiseled back after firing. The chiseling continues on the underside of the pan, where it likely rested on a transverse timber below the cover-pan joint.

OT 40) FT 237

No mends

Weight 0.6 kg

Pres. L. 13.6 cm, Pres. W. 12.4 cm

This fragment preserves inner margins of the pan rabbet near the front edge of an eaves combination tile with uncertain handedness. The upper surface is painted black.

OT 41) FP 334

No mends

Weight 0.7 kg

Pres. L. 10.5 cm, Pres. W. 11.8 cm

This fragment preserves the attached side of the cover of an eaves combination tile with uncertain handedness.

HIP COMBINATION TILES

Hip tiles also have symmetrical sides right and left of the hip line when viewed from the exterior corner of the building. Features within the right or left halves may be described in the same manner as the regular tiles, using the normal orientations of front/back and free/attached as seen from the exterior of the corresponding hip of the roof. For overall dimensions that incorporate both halves of the tile, the orientation of the left half of the tile is adopted.

L.: Longitudinal dimension of the full hip tile, from left to right, relative to its left half.

W.: Transverse dimension of the full hip tile, from front to back, relative to its left half.

Right/Left lateral overlap: The intended and actual overlaps of the next tile in the horizontal row are indicated by incised lines and weathering marks near the free end of the pan's upper surface. The hip tile has both a right and a left lateral overlap over the respective hip of the roof.

Right/Left rear overlap: The actual maximum rear overlap of the regular tile below may be represented by the width of the hip pan rabbet.

OT 42) FC 30

No mends
Weight 2.4 kg
Pres L. 24.3 cm, Pres. W. 22.1 cm, Thickness
ca. 2 cm (cover front faces)
Cover: L. 24.3 cm

This is a fragment from the cover of a hip combination tile. It is intact except for the right attached side.

The majority of the cover rabbet was chiseled back after firing.

OT 43) FC 67

Mended from 3 fragments
Weight 3.0 kg
Pres. L. 28.1 cm, Pres. W. 22.6 cm, Thickness
ca. 5 cm (pan interior)

This is a pan fragment from the hip line of a hip combination tile.

OT 44) FP 77

Mended from 3 fragments
Weight 7.7 kg
Pres. L. 50.8 cm, Pres. W. 28.8 cm, Thickness
ca. 5 cm (pan interior)
Cover: W. 25.7 cm
Pan: Left exposed L. 28.5 cm
Left rear overlap: Pan rabbet W. ca. 8 cm

This hip combination tile preserves the front side of the left pan half and the attached sides of the left and right cover halves. The middle section of the front edge of the left pan has been restored with plaster. The full length of the pan is intact beyond the lateral overlap zone. This is the only hip tile remaining which preserves the full longitudinal exposure of the pan.

An incised line and faint weathering marks coincide to indicate a relatively narrow left pan longitudinal exposure. A portion of the left pan rabbet preserves post-firing tooling.

The majority of the cover rabbet appears to have been chiseled after firing. The left pan rabbet is roughly hacked out toward its attached end.

OT 45) FC 79

No mends
 Weight 5.2 kg
 Pres. L. 25.6 cm, Pres. W. 27.5 cm, Thickness
 ca. 3-5 cm (cover front and lateral faces)
 Cover: L. 23.9-24.8 cm, W. 24.7-25.5 cm
 Right rear overlap: Pan rabbet W. 10.8 cm
 Left rear overlap: Pan rabbet W. 10.4 cm

Only the cover is intact from this hip combination tile.

The front and lateral faces of the cover are slightly oblique to one another in plan. These faces meet at an acute angle at front and back corners on the hip line and at an obtuse angle at the right and left corners of the cover.

The cover and pan rabbets were chiseled after firing. The original pre-firing cutting is intact at the inner margins of the cover rabbet, indicating that its floor was lowered by ca. 1 cm after firing.

OT 46) FP 156

Mended from 3 fragments
 Weight 8.5 kg
 Pres. L. 31.2 cm, Pres. W. 53.9 cm, Thickness
 ca. 5 cm (pan interior)
 Right lateral overlap: Incised line and
 weathering 12.6 cm
 Left lateral overlap: Weathering 9.4-10.4 cm

The right and left lateral faces of the pan are preserved from this hip combination tile.

The angle between the lateral faces is slightly acute in plan. Both lateral faces were cut back with a broad blade after the clay had dried leather hard, but the original uncut surface of the left lateral face is intact near the back corner.

OT 47) FT 226

No mends
 Weight 4.6 kg
 Pres. L. 30.3 cm, Pres. W. 34.2 cm, Thickness
 ca. 4 cm (pan interior)
 Left rear overlap: Pan rabbet W. 8.8-10.7 cm

The right and left lateral faces of the cover as well as the front faces of the left pan and cover are preserved from this hip combination tile.

The preserved portions of the left pan rabbet and the inner margins of the right pan rabbet and the cover rabbet were chiseled back after firing.

OT 48) FP 313

No mends
 Weight 1.4 kg
 Pres. L. 20.7 cm, Pres. W. 16.1 cm, Thickness
 ca. 4 cm (cover)
 Left rear overlap: Cover rabbet W. 9.4-10.1 cm

The left lateral and front faces of the cover are preserved from this hip combination tile.

The cover rabbet was chiseled after firing. The original pre-firing cutting is intact at the inner margins, indicating that the floor of the cover rabbet was lowered by ca. 1 cm to overlap the tile below.

OT 49) FP 314

No mends
 Weight 4.7 kg
 Pres. L. 29.2 cm, Pres. W. 26.4 cm, Thickness
 ca. 5 cm (pan interior)

The back lateral faces on the right and left sides of the cover and a portion of the pan are preserved from this hip combination tile.

The remains of the inner margins of the cover rabbet were cut before firing, and the back faces of the right and left pan rabbets were chiseled after firing.

OT 50) FP 315

Mended from 2 fragments
 Weight 2.8 kg
 Pres. L. 27.8 cm, Pres. W. 23.0 cm, Thickness
 ca. 5 cm (pan back edges)
 Left lateral overlap: Incised line and
 weathering 8.8 cm
 Right lateral overlap: Incised line 10.8-11.0 cm, Weathering 10.5-10.6 cm

The right and left lateral faces at the back corner of this hip combination tile are preserved.

Both lateral faces appear to have been chiseled back after firing using a broad blade. The bottom has large chips of temper embedded in its surface, and cavities left from plant material burned away during firing are an unusual feature for Old Temple tiles.

OT 51) FP 340

No mends

Weight 3.0 kg

Pres L. 27.4 cm, Pres W. 24.3 cm, Thickness
ca. 5 cm (pan lateral faces)

Right lateral overlap: Incised line 13.0-13.2
cm, Weathering 13.4 cm

Left lateral overlap: Incised line and
weathering 13.3 cm

This fragment preserves the right and left
lateral faces at the back corner of a hip
combination tile.

The diagonal hip line is articulated by an
incised line. The left lateral face has a finger

impression along its lower edge at the front break
edge. The right lateral face was chiseled back after
firing.

OT 52) FP 343

No mends

Weight 5.7 kg

Pres. L. 30.6 cm, Pres. W 44.2 cm, Thickness
ca. 3 cm (pan interior)

Left rear overlap: Pan rabbet W. 9.9-10.0 cm

This is a hip combination tile. The front face
and attached edge of the left pan and a portion of
right pan are preserved.

The pan rabbet was chiseled before firing.

RIDGE COMBINATION TILES

Ridge tiles have symmetrical sides right and left of the ridge line as seen from the free side of the cover. Within both halves, the orientations of free/attached and longitudinal/transverse are used as for the regular tiles. However, the front of the ridge tile is the free side of its cover, and the back is the free side of its pan.

Lateral overlap: The intended and actual overlaps of the next tile in the horizontal row are indicated by incised lines and weathering marks near the free end of the pan's upper surface.

OT 53) FC 31

Mended from 3 fragments
Weight 8.7 kg
L. 67.3 cm, W. 25.0 cm, Thickness ca. 3 cm
(pan front edge)
Cover: L. 25.5 cm
Pan: Total L. 41.8 cm, Exposed L. 28.3 cm (to incised line), Exposed L. 28.5 cm (to weathering line)
Lateral overlap: Incised line 13.3-13.7 cm, Weathering 12.9-13.7 cm

This ridge combination tile is nearly intact except for plaster restorations at the right free corner of the cover and along the sides of the pan. The cover is domed.

The upper surface of the pan was chiseled back after firing at its free end under the lateral overlap zone. Both pan bevels were chiseled, as are the majority of the surfaces on the bottom of the tile. The pre-firing tooling is intact below the center of the cover and the ridge line of the pan. A lip was cut before firing into the left pan rabbet's surface along its left edge.

OT 54) FC 61

Mended from 2 fragments
Weight 5.7 kg
Pres. L. 44.2 cm, W. 24.5 cm, Thickness ca. 3 cm (pan front edge), Thickness ca. 4 cm (cover front edge)
Cover: L. 25.4 cm

The domed cover and the attached side of the pan are intact from this ridge combination tile.

The majority of the cover rabbet was roughly hacked after firing, but traces of a lip ca. 4 cm wide running along its free edge were cut beforehand to accommodate the peaked profile at the back of a ridge tile pan. Long striations were left on the pan rabbets by pre-firing tooling, but the left rabbet was chiseled back along its outer edge.

OT 55) FR 100

No mends
Weight 4.6 kg
Pres. L. 29.0 cm, W. 24.9 cm, Thickness ca. 4 cm (pan)

The attached sides of the domed cover and pan are preserved from this ridge combination tile.

The cover and pan rabbets were cut out almost entirely before firing without later chiseling. The pan rabbets meet at a valley which is offset from the peak on the top of the pan. A raised lip ca. 3 cm wide runs along the outer edges of both the right and the left pan rabbets. Both lips were chiseled back after firing.

OT 56) FR 104

No mends
Weight 5.8 kg
Pres. L. 43.9 cm, W. 23.3 cm, Thickness ca. 2-3 cm (pan front edges)
Pan: L. 43.3 cm, Exposed L. 33.6 cm
Lateral overlap: Weathering 9.5-9.9 cm

The pan of this ridge combination tile is intact up to the joint with the cover.

Both pan bevels were chiseled back after firing, as is the whole of the underside.

OT 57) FR 105

Mended from 2 fragments
Weight 1.8 kg

The left front corner of the peaked cover of this ridge combination tile is preserved.

The cover rabbet was primarily cut out before firing with a raised lip ca. 0.03 cm wide along its outer edge.

OT 58) FR 106

No mends
Weight 2.6 kg
Pan: Pres. L. 19.4 cm, Pres. W. 29.2 cm,
Thickness ca. 3 cm (pan front edge)
Lateral overlap: Weathering 8.5-9.2 cm

This fragment preserves the left face and back end of the pan of a ridge combination tile.

The lateral overlap zone of the top of the pan was chiseled back after firing, as was the majority of the left pan bevel.

The pan rabbets were primarily cut out before firing except for a band of chiseling along the outer left edge.

OT 59) FR 107

No mends
Weight 0.4 kg
Pres. L. 10.7 cm, Pres. W. 8.0 cm

The attached side of the peaked cover is preserved from this ridge combination tile.

The underside was chiseled back after firing.

OT 60) FR 108

No mends
Weight 0.4 kg
Pres. L. 10.4 cm, Pres. W. 12.4 cm, Thickness
ca. 5 cm (cover peak)

Only the interior of the peaked cover of this ridge combination tile is preserved.

The cover rabbet was chiseled back after firing.

OT 61) FR 117

No mends
Weight ca. 4.5 kg (est.)
Pres. L. 22.7 cm, W. 24.2 cm, Thickness ca. 7
cm (pan front edge)

The attached sides of the domed cover and pan are preserved from this combination ridge tile.

Two nails were driven through the right and left halves of the pan roughly perpendicular to the slope. The nails are centered on both gables and ca. 5 cm from the attachment to the cover. The nails were countersunk in a depression ca. 4 cm in diameter over two round shafts, both 1.2 cm in diameter. At the edges of both shafts are traces of two narrower shafts which slope at slightly different angles and clearly were cut beforehand. The nail holes appear to have been cut out entirely after firing. They were started with a small drill for the narrow shafts, expanded with a wider drill for the prominent nail shafts, and finished by cutting the countersink with a chisel. No macroscopic traces of corrosion from the nails remain.

The pre-firing cutting of the pan rabbets is intact on the underside. A lip ca. 4 cm wide raised as much as ca. 2 cm above the inner rabbet surfaces runs along both the right and left edges of the rabbets. Most of the lip surfaces have been roughly hacked back or broken away after firing, but portions of the lip are completely uncut molded surfaces whose consistency is similar to the beddings of regular tiles.

Although the distinctive fabric and profiles of the tile suggest it belonged to the Old Temple, the nail holes and the thickness of the pan are unusual. It is possible that this was the first ridge tile set on the top row, and, thus, the nails ensured it was not shifted by wind. The thickness can be attributed to the relative lack of post-firing tooling on the underside, although the tile might have been a replacement fabricated after the installation of the roof.

OT 62) FT 215

No mends
Weight 0.8 kg
Cover: Pres. L. 16.3 cm, Pres. W. 13.6 cm,
Thickness ca. 4 cm (cover)

The front face and part of the left face are preserved from the domed cover of a ridge combination tile.

The majority of the cover rabbet was chiseled after firing, but a lip ca. 3 cm wide running along the front edge was cut into the bottom of the tile before firing.

OT 63) FT 223

Mended from 2 fragments

Weight 1.35 kg

Pres. L. 17.6 cm, Pres. W. 17.0 cm, Thickness
ca. 4 cm (cover front edge)

The attached side and the left face of the peaked cover are preserved from this ridge combination tile.

Pre-firing tooling is preserved toward the interior of the cover rabbet. A lip running along its left edge was chiseled back after firing.

OT 64) FT 227

Mended from ca. 4 fragments

Weight 5.9 kg

Pres. L. 46.1 cm, W. 24.2 cm, Thickness ca 4
cm (pan front edge)

Pan: Total L. 41.2 cm, Exposed L. 30.7-31.7
cm (to incised line), Exposed L. 31.5 cm
(to weathering)

Lateral overlap: Incised line 9.5-10.6 cm,
Weathering 9.3-9.9 cm

The pan is intact from this ridge combination tile.

The upper surface of the pan was chiseled after firing at its free end under the lateral overlap zone. Both pan bevels were chiseled back, but the back face of the pan was only cut out before firing. There are weathering stains from the notch of the tile below on both the right and left faces of the pan at its attached end.

Long striations from pre-firing tooling cover most of the pan rabbet faces, which meet at an irregular valley that is only approximately aligned with the ridge peak on the upper surface. A lip ca. 3 cm wide runs along the outer edges of both the right and the left pan rabbets. Both lips were chiseled back after firing.

OT 65) FP 294

No mends

Weight 1.7 kg

Pres. L. 11.6 cm, Pres. W. 12.8 cm, Thickness
ca. 4 cm (cover front edge)

This is a small fragment of the left attached corner of the cover from a ridge combination tile. The cover rabbet was chiseled after firing.

FREE COVER TILES

The free cover is oriented and described as an equivalent to the cover of a regular or eaves tiles. However, because there is no attached end, the orientation of a free cover may be described as having right and left sides only when viewed from the front.

OT 66) FC 78

Mended from 6 fragments
Weight 3.0 kg (plaster additions)
L. 24.6 cm, Pres. W. 29.7 cm, Thickness ca. 3 cm (cover sides)

This fragment preserves the front end of a regular free cover tile. Although less than a third of the tile remains, it was restored fully in plaster.

OT 67) FC 96

Mended from 2 fragments
Weight 4.5 kg
L. 25.0 cm, Pres. W. 36.4 cm, Thickness ca. 2-4 cm
Rear overlap: Incised line 9.1-9.3 cm,
Weathering 8.9-9.1 cm

The back right corner and the full longitudinal dimension of this regular free cover tile are preserved.

The shank of an iron nail driven into the top behind the incised lines remains embedded in the tile. The nail head appears to have broken off, revealing a countersink hacked into the tile after firing.

Two cover bevels at the back corners were re-cut after firing. Part of the inner face of a notch cut before firing is preserved on the left side. Preserved inside the right bevel is the inner corner of a notch whose faces have post-firing tooling marks.

On the underside, long striations are preserved over the right half from cutting out a cover rabbit before firing. The left half and the margins along the lower right edge were tooled after firing.

The tooling patterns suggest a right-handed regular tile was converted by separating its cover and cutting the countersunk nail hole after firing.

OT 68) FC 98

Mended from 2 fragments
Weight 2.4 kg
L. 24.9 cm, Pres. W. 22.9 cm, Thickness ca. 2-4 cm
Rear overlap: Incised lines 9.3-9.8 cm,
Weathering 9.3-9.7 cm

The back end of this regular free cover tile is preserved.

The shank and part of the head of an iron nail driven into the top overlap zone remains embedded in the tile. The countersink for the nail head is rectangular, 1.9 x 2.4 cm in plan, and ca. 2 cm deep. While inspecting the surfaces exposed during conservation in 2004, it appeared the depression was probably cut into the tile before firing.

A bevel was cut into the back right corner of the tile before firing, but it has been removed except for its back margins by a notch cut into the right side after firing. A second notch on the left side was cut before firing and expanded at its lower margins afterwards.

On the underside, long striations are preserved over the right half from cutting out a cover rabbit before firing. The left half and the margins along the lower right edge were tooled after firing.

The tooling patterns suggest a complete right-handed regular tile was converted into a free cover after firing.

OT 69) FC 107

No mends
Weight 0.6 kg
Pres. L. 13.3 cm, Pres. W. 14.9 cm, Thickness ca. 2-3 cm

This fragment preserves the free side of a cover tile of indeterminate type. A hole 0.9 cm in diameter in this tile is drilled 2.0 cm from the right

edge, but its location is not typical of free cover tiles.

OT 70) FC 108

No mends

Weight 0.5 kg

Pres. L. 13.3 cm, Pres. W. 11.1 cm, Thickness
ca. 5 cm

This is a fragment from near the back end of a free cover tile. A nail hole ca 0.8 cm in diameter was drilled through the tile, but it is unclear whether this occurred before or after firing.

OT 71) FC 109

No mends

Weight 2.3 kg

Pres. L. 18.8 cm, Pres. W. 29.1 cm, Thickness
ca. 2-3 cm

The right lateral edge as far back as the outer margins of the right cover bevel is preserved from this regular free cover tile. The finished surfaces of the tile are coated with black paint up to the back edges of the tile. The paint is consistently grayish brown with streaks of reddish orange, probably due to the thinning of its application.

Corrosion from the shank of an iron nail driven into the top overlap zone remains on the surfaces of the tile. The tile has broken away around the shaft, exposing the hole in section. The nail head was countersunk in a round 1.1 cm depression roughly 2.4 cm in diameter with a narrower round shaft centered below it. The surfaces of the countersink indicate it was drilled from above while the clay was still damp, which left centripetal striations on the side walls and opened cracks on its floor.

The face of the right cover bevel was cut before firing. Long striations from pre-firing cutting are preserved over most of the underside

except where it was later chiseled back along its right and left margins.

The tooling patterns suggest either that this free cover was formed specially in a regular tile mold or that a complete left-handed regular tile was converted into a free cover before firing.

OT 72) FC 110

No mends

Weight 1.7 kg

Pres. L. 18.1 cm, Pres. W. 20.5 cm, Thickness
ca. 3 cm

One lateral face of this regular free cover tile is preserved. The finished surfaces of the tile are coated with a reddish brown paint interspersed with streaks of dark gray.

Long striations indicate the underside was cut out before firing except for a band of chiseling running along the lateral edge ca 4-5 cm wide.

OT 73) FT 219

No mends

Weight 0.1 kg

Pres. L. 8.3 cm, Pres. W. 5.5 cm, Thickness
3.0 cm (front cover peak)

The front face at the peak is preserved from this eaves free cover. The underside was chiseled after firing.

OT 74) FT 220

No mends

Weight 1.8 kg

Pres. L. 16.8 cm, Pres. W. 14.0 cm, Thickness
3.2 cm (front cover peak)

The front right corner is preserved from this eaves free cover. The underside was chiseled after firing.

EAVES COMBINATION TILES USED AS REGULAR TILES

OT 75) FC 83

No mends

Weight 0.4 kg

Pres. L. 12.3 cm, Pres. W. 10.4 cm, Thickness
ca. 3 cm (pan)

This fragment preserves the attached front corners of the cover and pan of a left-handed re-cut eaves combination tile.

The identification of the tile is secured by the 0.7 cm inset of the cover from the front edge of the pan. The chiseling patterns on the pan rabbet are characteristic of the type.

length of the pan at its front edge, the front of the pan bevel, and part of the attached front corner of the cover.

The cover is set back 0.8 cm from the front edge of the pan, and the intact portion of its upper edge matches the profile of an eaves tile cover. The pan bevel was cut after firing. The pan rabbet was cut after firing with a narrow chisel in organized rows of short strokes proceeding from the front face toward the interior of the tile. The cover rabbet was cut after firing to fit over a regular tile below, diminishing the cover to only 2.1 cm thick at the break.

OT 76) FC 114

No mends

Weight 0.2 kg

Pres. L. 7.9 cm, Pres. W. 7.8 cm, Thickness
ca. 2 cm (cover front edge)

This is a fragment of the front free corner of a cover of a re-cut eaves combination tile.

The profile is typical of an eaves tile, but the cover rabbet was chiseled after firing to fit over the cover bevel a tile below, indicating that the tile was placed above the eaves row.

OT 78) FT 225

No mends

Weight 0.5 kg

Pres. L. 14.2 cm, Pres. W. 9.9 cm, Thickness
ca 3 cm (pan front edge)

This fragment preserves the attached front corners of the cover and pan of a left-handed re-cut eaves combination tile.

Its identification is secured by the 0.9 cm inset of the cover from the front edge of the pan. The chiseling patterns on the pan rabbet are characteristic of the type.

OT 77) FT 218

Mended from 4 fragments

Weight 2.0 kg

Pres. L. 38.2 cm, Pres. W. 12.9 cm, Thickness
ca. 3 cm (pan front edge)

Pan: Exposed L. 30.3-30.9 cm (to incised lines), Exposed L. 30.9-31.9 cm (to weathering)

This fragment of a right-handed re-cut eaves combination eaves tile preserves the exposed

OT 79) FP 310

No mends

Weight 0.3 kg

Pres. L. 4.6 cm, Pres. W. 10.7 cm

This fragment preserves the attached front corner of the cover of a right-handed re-cut eaves combination tile.

The cover rabbet was chiseled back to fit over the notch of a tile in the row below.

TILES OF UNCERTAIN IDENTIFICATION

Because most tiles from the Old Temple roof were generating using the same cover and pan profiles, too little is preserved in many of the fragments to identify the type with certainty.

Regular combination or free cover tile

OT 80) FC 113

No mends

Weight 0.4 kg

Cover: Pres. L. 10.5 cm, Pres. W. 11.8 cm, Thickness ca. 3 cm (cover edges)

This fragment preserves the front free corner of either a right-handed combination tile or a free cover.

Eaves combination or free cover tiles

OT 81) FC 84

Mended from 2 fragments

Weight 0.5 kg

Pres. L. 14.9 cm, Pres. W. 15.0 cm, Thickness
ca. 2 cm (cover interior)

This fragment preserves the interior of an eaves cover from either a combination tile of uncertain handedness or a free cover.

OT 82) FC 85

No mends

Weight 0.7 kg

Pres. L. 12.2 cm, Pres. W. 14.2 cm, Thickness
ca. 3-4 cm

This fragment preserves the free edge of an eaves cover near its front from either a combination tile of uncertain handedness or a free cover.

OT 83) FT 212

No mends

Weight 0.6 kg

Pres. L. 12.5 cm, Pres. W. 11.3 cm, Thickness
ca. 4 cm (cover free edge)

This fragment preserves the free edge of an eaves cover near its front from either a combination tile of uncertain handedness or a free cover.

OT 84) FT 213

No mends

Weight 0.6 kg

Pres. L. 14.5 cm, Pres. W. 14.2 cm, Thickness
ca. 3 cm

This is a fragment of the front right corner of an eaves cover tile. Too little of the cover is intact to determine with certainty whether the cover was free or a right-handed combination tile.

The underside was chiseled after firing.

OT 85) FT 214

No mends

Weight 0.8 kg

Pres. L. 13.6 cm, Pres. W. 16.0 cm, Thickness
ca. 3 cm

This fragment preserves the front free corner of an eaves cover from either a left-handed combination tile or a free cover.

All but a small region on the interior of the cover rabbet was chiseled after firing.

OT 86) FT 216

No mends

Weight 0.3 kg

Pres. L. 9.3 cm, Pres. W. 8.5 cm, Thickness
ca. 3 cm

This fragment preserves the front free corner of an eaves cover from either a left-handed combination tile or a free cover.

All but a small region on the interior of the cover rabbet was chiseled after firing.

OT 87) FT 221

No mends

Weight 0.3 kg

Pres. L. 11.4 cm, Pres. W. 10.3 cm, Thickness ca. 2 cm

This fragment preserves the front free corner of an eaves cover from either a right-handed combination tile or a free cover.

Regular or eaves combination tiles

OT 89) FC 32

No mends

Weight 3.1 kg

Pres. L. 17.0 cm, Pres. W. 28.4 cm, Thickness ca. 4 cm (pan interior)

This fragment preserves the attached sides of the cover and pan of a right-handed combination tile. Too little is preserved to determine whether the tile is an eaves or regular tile.

The finished surfaces were coated with a brown paint with red streaks.

The face of the notch was chiseled after firing.

OT 90) FC 62

Mended from 2 fragments

Weight 6.3 kg

Pres. L. 28.4 cm, Pres. W. 33.3 cm

Cover: L. 25.1 cm

Rear overlap: Notch W. 7.5 cm, Incised line and weathering 7.5 cm

This fragment preserves the back end of the cover and the attached side of the pan of a right-handed combination tile. Too little of the cover profile near the front is preserved to determine whether the tile is an eaves or regular tile.

OT 91) FC 65

Mended from 4 fragments

Weight 2.9 kg

Pres. L. 22.3 cm, Pres. W. 24.2 cm, Thickness ca. 5 cm (cover interior)

Rear overlap: Notch W. 8.3-8.4 cm

The underside was chiseled after firing.

OT 88) FT 222

No mends

Weight 0.6 kg

Pres. L. 9.2 cm, Pres. W. 16.2 cm, Thickness ca. 2-4 cm

This fragment preserves the front free corner of an eaves cover from either a left-handed combination tile or a free cover.

Only the outer margins of the cover rabbet along the front and free edges were chiseled after firing.

This fragment preserves the back face and the free side of a right-handed combination tile. Too little is preserved to determine whether the tile is an eaves or regular tile.

The cover bevel and part of the notch are preserved.

The upper surfaces of the tile are greenish gray with a bubbly, glassy patina that suggests the clay was heated past its point of vitrification. It is unclear whether the piece was over fired or burned in a secondary fire. The tile was chiseled after firing along the upper and lower back edges of the cover, suggesting it was used on the roof.

OT 92) FC 66

No mends

Weight 0.7 kg

Pres. L. 13.0 cm, Pres. W. 14.6 cm

This fragment preserves the back free corner and bevel of the cover of a right-handed combination tile. Too little is preserved to determine whether the tile is an eaves or regular tile.

OT 93) FP 108

No mends

Weight 3.6 kg

Pres. L. 25.2 cm, Pres. W. 26.3 cm, Thickness ca. 4 cm (pan edges)

Lateral overlap: Incised line 10.1 cm,

Weathering 10.3 cm

Rear overlap: Incised line 10.4-10.6 cm

This fragment preserves the back free corner of the pan of a right-handed combination tile. Too

little is preserved to determine whether the tile is an eaves or regular tile.

The finished upper surface preserves a few traces of a dark black paint.

OT 94) FP 109

No mends

Weight 2.2 kg

Pres. L. 21.4 cm, Pres. W. 23.0 cm, Thickness ca. 4 cm

Lateral overlap: Incised line 12.4-12.6 cm, Weathering 12.3 cm

Rear overlap: Incised line 6.5-7.5 cm, Weathering 8.0 cm

This fragment preserves the back free corner of the pan of a left-handed combination tile. Too little is preserved to determine whether the tile is an eaves or regular tile.

OT 95) FC 115

Mended from 3 fragments

Weight 1.6 kg

Pres. L. 9.8 cm, Pres. W. 33.5 cm

This fragment preserves the free side and bevel of the cover of a left-handed combination tile. Too little is preserved to determine whether the tile is an eaves or regular tile.

OT 96) FP 159

No mends

Weight 5.1 kg

Pres. L. 32.8 cm, Pres. W. 33.0 cm, Thickness ca. 4 cm (pan interior)

Rear overlap: Notch W. 9.8, Weathering 9.8-10.0 cm

This fragment preserves the back attached side of the pan of a left-handed combination tile. Too little is preserved to determine whether the tile is an eaves or regular tile.

The finished upper surface of the pan is coated in an even black paint to near its back edge, where two flecks of paint dripped over the buff slip along the back edge of the tile.

The notch was cut after firing to coincide with a faint patch of pale material which probably indicates the actual position of the tile above.

OT 97) FT 217

No mends

Weight 1.5 kg

Pres. L. 20.7 cm, Pres. W. 15.9 cm, Thickness 3-4 cm (cover edges)

Rear overlap: Incised line and weathering 8.5-9.0 cm

This fragment preserves the back and free side faces of the cover of a right-handed combination tile. Too little is preserved to determine whether the tile is an eaves or regular tile.

The cover bevel and lateral face of the notch were only tooled before firing. An unusual second bevel was cut into the attached side of the cover after firing through the back portion of the lateral wall of the notch. This cutting may have accommodated the pan bevel of a left-handed tile above, suggesting the handedness of tiles was not always consistent within each vertical row. Some free cover tiles preserve a second cover bevel, but the only other combination tile preserving the second bevel, FT 209, is an eaves tile, which suggests that this tile too is likely to have been an eaves tile.

OT 98) FP 266

Mended from 3 fragments

Weight 5.5 kg

Pres. L. 26.1 cm, Pres. W. 36.5 cm, Thickness ca. 4 cm (cover interior)

Rear overlap: Notch W. 8.2 cm

This fragment preserves the back end of the cover and the attached side of the pan of a left-handed combination tile. Too little is preserved to determine whether the tile is an eaves or regular tile.

The finished surfaces of the tile are coated in a brown paint with streaks of red concentrated toward the back edge of the cover.

OT 99) FP 288

No mends

Weight 2.4 kg

Pres. L. 16.8 cm, Pres. W. 26.4 cm, Thickness ca. 4 cm (pan edges and interior)

Rear Overlap: Incised line and weathering 12.3-12.5 cm

This fragment preserves the back face of the pan near its attached end of a left-handed combination tile. Too little is preserved to determine whether the tile is an eaves or regular tile.

The finished upper surface is coated with a heavily-abraded reddish orange paint which darkens to brown at its back edge near the back of the tile.

OT 100)FP 330

No mends
 Weight 1.5 kg
 Pres. L. 17.2 cm, Pres. W. 16.2 cm

This fragment preserves the attached sides of the cover and pan near the back end of a right-handed combination tile. Too little is preserved to determine whether the tile is an eaves or regular tile.

A wad of fine slip was wiped over the front face of the notch, demonstrating that the tile was finished with slip after the notch had been cut out.

OT 101)FP 332

No mends
 Weight 0.6 kg
 Cover: Pres. L. 13.1 cm, Pres. W. 16.8 cm

This fragment preserves the cover bevel of a left-handed combination tile. Too little is preserved to determine whether the tile is an eaves or regular tile.

The finished upper surface is coated with a crackly dark reddish brown paint.

OT 102)FP 336

No mends
 Weight 1.0 kg
 Pan: Pres. L. 19.2 cm, Pres. W. 11.2 cm,
 Thickness ca. 4 cm (pan interior)

This fragment preserves the back attached corner of the pan of a combination tile. Too little is preserved to determine whether the tile is an eaves or regular tile.

The finished upper surface is coated in a dark black paint to near the back edge. The paint fades to a dull orange along its back edge.

The area of the notch was chiseled after firing to a longitudinal dimension of 9.2 cm, although it is not clear whether just the back end or the entirety of the cover was removed. Possibly the tile was used as a free pan, where it would have been paired with a free cover to replace a damaged combination tile.

OT 103)FP 338

No mends
 Weight 1.2 kg
 Pres. L. 15.0 cm, Pres. W. 12.8 cm, Thickness
 ca. 5 cm (back face)

This fragment preserves the back attached corner of a left-handed combination tile. Too little of the pan profile near the front is preserved to determine whether the tile is an eaves or regular tile.

OT 104)FP 342

No mends
 Weight 5.9 kg
 Pres. L. 23.7 cm, Pres. W. 34.9 cm, Thickness
 ca. 4 cm (cover and pan interior)
 Rear overlap: Notch W. 9.1 cm, Weathering
 8.9-9.1 cm

This fragment of a left-handed combination tile preserves the attached sides of the cover and pan as well as the back face of the pan. Too little is preserved to determine whether the tile is an eaves or regular tile.

The transverse dimension of the notch was increased after firing where it coincides with the actual overlap of the tile above indicated by the weathering.

OT 105)FP 344

No mends
 Weight 1.4 kg
 Pres. L. 24.4 cm, Pres. W. 12.5 cm, Thickness
 ca. 4 cm (pan free edge)
 Lateral overlap: Incised line and weathering
 9.9 cm

This fragment preserves the free face of the pan of a combination tile of uncertain handedness. Too little is preserved to determine whether the tile is an eaves or regular tile.

OT 106)FP 345

No mends
 Weight 2.5 kg
 Pres. L. 23.1 cm, Pres. W. 21.7 cm, Thickness
 ca. 4 cm (pan edges and interior) Lateral
 overlap: Weathering 9.6 cm
 Rear overlap: Incised line and weathering 7.8
 cm

This fragment preserves the back free corner of a right-handed combination tile. Too little is preserved to determine whether the tile is an eaves or regular tile.

Regular or hip combination tiles

OT 107)FP 104

No mends
Weight 3.5 kg
Pres. L. 23.5 cm, Pres. W. 33.4 cm, Thickness
ca. 4 cm (pan edges and interior)
Right Lateral Overlap: Incised line 13.8-14.1
cm, Weathering 13.4-13.8 cm

This fragment preserves the front free corner of the pan of either a regular left-handed combination tile or the right half of a hip combination tile.

Faint finger impressions are preserved on the free face. The pan bevel and rabbet were chiseled after firing.

OT 108)FP 105

No mends
Weight 3.6 kg
Pres. L. 30.5 cm, Pres. W. 30.5 cm, Thickness
ca. 4 cm (pan front edge)
Rear overlap: Pan rabbet W. 11.5-12.0 cm

This fragment preserves the front face and part of the bevel of the pan from either a regular right-handed combination tile or the left half of a hip combination tile.

The pan bevel and rabbet were chiseled after firing.

OT 109)FP 106

No mends
Weight 1.1 kg
Pres. L. 16.1 cm, Pres. W. 17.0 cm, Thickness
ca. 4 cm (pan front edge)

This fragment preserves the front face and part of the bevel of the pan from either a regular right-handed combination tile or the left half of a hip combination tile.

The pan bevel was chiseled after firing to create a transverse inset of 1.6 cm, accommodating a slight irregularity in the normal overlap.

OT 110)FP 107

No mends
Weight 3.4 kg
Pres. L. 27.0 cm, Pres. W. 23.3 cm, Thickness
ca. 4 cm (pan front edge)
Rear overlap: Pan rabbet W. 9.3-10.0 cm

This fragment preserves the front face and part of the bevel of a pan from either a regular left-handed combination tile or the right half of a hip combination tile.

The pan bevel was chiseled after firing to a create a transverse inset of 1.9 cm, accommodating a slight irregularity in the normal overlap.

OT 111)FP 309

Mended from 2 fragments
Weight 4.4 kg
Pan: Pres. L. 21.5 cm, Pres. W. 47.5 cm,
Thickness ca. 3 cm (pan free edge)

This fragment preserves the free side and part of the bevel of the pan from either a regular left-handed combination tile or the right half of a hip combination tile.

The surfaces of the tile are greenish gray with a bubbly, glassy patina that suggests the clay was heated past its point of vitrification. It is unclear whether the piece was over fired or burned in a secondary fire. The pan rabbet and the underside along its free edge were chiseled after firing, suggesting the tile was installed on the roof.

OT 112)FP 311

No mends
Weight 1.8 kg
Pres. L. 18.2 cm, Pres. W. 21.6 cm, Thickness
ca. 4 cm (pan edges)

This fragment preserves the free side and the inner margin of the rabbet of a pan from either a regular right-handed combination tile or the left half of a hip combination tile.

The finished upper surface is coated in a crackly dark black paint. Finger impressions are preserved along the lower edge of the lateral face.

OT 113)FP 318

No mends
Weight 1.4 kg
Pres. L. 17.8, Pres. W. 17.8, Thickness ca. 4
cm (pan edges)

This fragment preserves the front face and part of the bevel of a pan from either a regular right-handed combination tile or the left half of a hip combination tile.

OT 114)FP 339

No mends

Weight 1.7 kg

Pan: Pres. L. 24.0 cm, Pres. W. 16.7 cm,

Thickness ca. 4 cm (pan interior)

This fragment preserves the bevel and rabbet of the pan from either a regular right-handed combination tile or the left half of a hip combination tile.

The pan bevel and rabbet were chiseled back after firing.

Regular or eaves combination or free cover tile

OT 115)FC 116

No mends

Weight 0.5 kg

Pres. L. 13.8 cm, Pres. W. 12.9 cm, Thickness ca. 3 cm (cover back edge)

This fragment preserves the back face and bevel of the cover of a free cover or a left-handed combination tile. Too little of the cover profile near the front is preserved to determine whether the tile is an eaves or regular tile.

The finished upper surface is coated with a dark black slip to near the back edge, where it fades to a streaky reddish orange.

Fragments of undetermined type

OT 116)FP 312

No mends

Weight 0.4 kg

Pres. L. 12.0 cm, Pres. W. 10.3 cm, Thickness ca. 4 cm

Pres. L. 1.8 cm, Pres. W. 20.0 cm, Thickness ca. 5 cm (pan interior)

This fragment preserves the front edge and bevel of a pan of any type of combination tile.

The finished surfaces of the tile are coated in a black paint with a slight gloss.

This fragment preserves the interior of the pan with the inner margins of the rabbet from either a regular, eaves, or hip combination tile. The handedness is unknown.

The underside has a series of folds running oblique to the tile, perhaps a result of inadequate packing of the clay while the tile was being formed.

OT 117)FP 317

No mends

Weight 1.1 kg

Pres. L. 11.4 cm, Pres. W. 16.0 cm, Thickness ca. 4 cm

This fragment preserves the back face of a pan from a regular, eaves, or hip combination tile.

The finished upper surface is coated with a dark black paint to near its back edge, where one stroke has faded to a brownish orange. A fleck of paint has dribbled toward the back of the tile over the unpainted back margin.

Because no hip tiles are known with black paint, it is more likely that this belonged to a regular or eaves tile.

OT 119)FP 331

No mends

Weight 0.8 kg

Pres. L. 16.3 cm, Pres. W. 12.4 cm, Thickness ca. 4 cm

This fragment comes from the interior of a pan of a regular, eaves, or hip combination tile.

OT 120)FP 335

No mends

Weight 0.5 kg

Pres. L. 13.4 cm, Pres. W. 11.0 cm, Thickness ca. 4 cm

Lateral overlap: Incised line 11.3 cm

This fragment preserves the free face and part of the bevel of a left-handed regular or eaves combination tile or the right half of a hip combination tile.

OT 118)FP 326

No mends

Weight 1.8 kg

The finished upper surface is coated with a dull red brown paint.

Lateral overlap: Incised line and weathering
12.8-13.0 cm

OT 121)FP 341

No mends

Weight 1.9 kg

Pres. L. 22.0 cm, Pres. W. 19.0 cm, Thickness
ca. 5 cm (pan interior)

This fragment preserves the free face of the pan of a combination tile of uncertain handedness. Too little is preserved to determine whether the tile is an eaves, regular, or hip tile.

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